9. GULF OF ALASKA NORTHERN ROCKFISH

by

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9.0 Executive Summary

Summary of Major Changes

For northern rockfish, an alternative age structured model (Model 5) is recommended for this year with updated data. The alternative model allows for estimation of natural mortality with an informative lognormal prior and estimation of average historical fishing mortality in computations of initial numbers at age in 1977.

Input Data

The model was updated to include the 2005 survey biomass estimate, updated catch from 2004, preliminary catch for 2005, survey age composition from 2003, new fishery age compositions from 2003 and 2004, and updated fishery age compositions from a backlog of available otoliths for the years 2000 – 2002. Fishery length compositions were removed for the years 1998-2003 because fishery age compositions were utilized for these years.

Assessment Methodology

The age structured model from the last full SAFE (2003) was modified for this year. Five alternatives were considered. Model 1 was the same as the last full SAFE (2003). Model 2 was the alternative case from the last full SAFE (2003). Model 2 reduced likelihood weighting components, removed the Beverton Holt spawner-recruit (S-R) relationship, and re-parameterized the penalties on fishing mortality regularity. Model 3 modified Model 2 to allow for the estimation of natural mortality with an informative lognormal prior. Model 4 modified Model 2 to estimate historical fishing mortality in computations of initial numbers at age in 1977. Model 5 modified Model 2 to allow for both the estimation of natural mortality with an informative lognormal prior and the estimation of historical fishing mortality in computations of initial numbers at age in 1977.

Assessment Results

Model 5 is recommended for this year's assessment. Model 5 had the best fit to increased biomass from the 2005 NMFS bottom trawl survey and had the best overall fit to the data (lowest overall unweighted objective function). Based on Model 5, the recommended ABC for 2006 is 5,891 mt. The corresponding reference values for northern rockfish recommended for this year and projected one additional year are summarized below:

Summary	**2006**[1]	2007[2]
$B_{40\%}$ (mt)	**29,559**	29,559
Female Spawning Biomass (mt)	**36,199**	35,988
$F_{40\%}$	**0.062**	0.062
F_{ABC} (max. $F_{40\%}$)	**0.062**	0.062
ABC (mt, maximum allowable)	**5,891**	5,802
F_{OFL} ($F_{35\%}$)	**0.075**	0.075
OFL (mt, $F_{35\%}$)	**7,033**	7,277

[1] Recommended for ABC

[2]The 2007 ABC and OFL were projected using an expected catch value of 5.702 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author's F method was used for this projection (Table 9-13) in response to management requests for a more accurate one-year projection.

This year's recommended ABC is the maximum allowable ABC under Tier-3. This year's recommended ABC is 13 % higher than last year's recommended ABC. The increased ABC reflects the change in F40, which is about 8% higher than in 2004 as a result of separating survey and fishery selectivity. The increased ABC also reflects the estimated 27% increase in projected 6+ total biomass over 2004. However, precaution is warranted for the management of Gulf of Alaska northern rockfish because there is considerable uncertainty in the survey biomass estimates and because of evidence of localized depletion discussed below.

<u>Response to 2004 SSC Comments</u>

SSC Comments to the Assessment Authors: Regarding the contribution of older females to stock productivity, the SSC requests that the SAFE authors examine the consequences for rockfish management in both the BSAI and GOA if it is true that older females have a disproportionate large contribution to stock productivity and are also disproportionately harvested due to their size. We request that this type of management strategy evaluation be done for those species for which loss of older females is most prevalent or suspected. We also request that an evaluation of the actual degree of loss of older aged females be provided, including an evaluation of how to adjust for early fishery data where there may have been intense fishing prior to historic age collections. We encourage comparison of BSAI and GOA results.

Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. The AFSC has funded a project to the REFM Division to determine if this relationship occurs for Pacific ocean perch in the Central Gulf of Alaska (See section 9.1.4).

A parameter was added to this year's assessment model to estimate average historic fishing mortality in computations of initial numbers at age in 1977. Incorporating historic fishing mortality results in a better fit to recent high biomass estimates (See section 9.7). However, an evaluation of the actual degree of loss of older aged females, including an evaluation of how to adjust for early fishery data where there may have been intense fishing prior to historic age, was not conducted for northern rockfish.

<u>Response to 2003 SSC Comments on Northern Rockfish Depletion</u>

In the SAFE the stock assessment authors indicates that a study of the northern rockfish fishery for the period 1990-98 showed that an estimated 89% of the catch was taken from just five relatively small fishing grounds: Portlock Bank, Albatross Bank, an unnamed bank south of Kodiak Island that fishermen commonly refer to as the "Snakehead", Shumagin Bank, and Davidson Bank. In particular, Snakehead was the most important fishing ground, as it accounted for 46% of the catch during these years. The SSC requested examination of this fishery feature to determine if there is any biological significance.

Results of an analysis of localized depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium. The use of Leslie depletion estimators on targeted rockfish catches detected relatively few localized depletions for northern rockfish. Several significant depletions occurred in the early 1990s for northern rockfish, but were not detected again by the depletion analysis. However, when fishery and survey CPUEs were plotted over time for a block of high rockfish fishing intensity that contained the "Snakehead", the results indicated there were year-over-year drops in both fishery and survey CPUE for northern rockfish. Presently, fishing for northern rockfish is nearly absent relative to previous effort in the area. The significance of these observations depend on the migratory and stock structure patterns of northern rockfish. If fine-scale stock structure is determined in northern rockfish, or if the area is essential to northern rockfish reproductive success, then these results would suggest that current apportionment of ABC may not be sufficient to protect northern rockfish from localized depletion.

9.1 INTRODUCTION

9.1.1 General Distribution

The northern rockfish, *Sebastes polyspinis*, is a locally abundant and commercially valuable member of its genus in Alaskan waters. As implied by its common name, northern rockfish has one of the most northerly distributions among the 60+ species of *Sebastes* in the North Pacific Ocean. It ranges from extreme northern British Columbia around the northern Pacific Rim to eastern Kamchatka and the northern Kurile Islands and also north into the eastern Bering Sea (Allen and Smith 1988). Within this range, northern rockfish are most abundant in Alaska waters, from the western end of the Aleutian Islands to Portlock Bank in the central Gulf of Alaska (Clausen and Heifetz 2002).

9.1.2 GOA Management Units

Since 1988, the North Pacific Fishery Management Council (NPFMC) has managed northern rockfish in the Gulf of Alaska as part of the slope rockfish assemblage. In 1991, the NPFMC divided the slope rockfish assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. These subgroups were established to protect Pacific ocean perch, shortraker/rougheye, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC (acceptable biological catch) and TAC (total allowable catch). Prior to 1991, an ABC and TAC were assigned to the entire assemblage. ABC and TAC for each subgroup, including northern rockfish, is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on the average distribution of exploitable biomass from the three most recent Gulf of Alaska trawl surveys. Exploitable biomass for slope rockfish apportionment is calculated as the average of the three most recent trawl survey biomass estimates for depths greater than 100 m. Northern rockfish are relatively scarce in the eastern Gulf of Alaska, and the ABC apportioned to the Eastern Gulf management area is small. This small ABC is generally too difficult to be managed effectively as a directed fishery. Since 1999, the ABC for northern rockfish apportioned to the Eastern Gulf management area is included in the West Yakutat ABC for “other slope rockfish.”

9.1.3 Evidence of Stock Structure

Gulf of Alaska northern rockfish grow significantly faster and reach a larger maximum length than Aleutian Islands northern rockfish (Clausen and Heifetz 2002). However, a genetic study of northern rockfish collected at three locations near the western Aleutian Islands, the western Gulf of Alaska, and Kodiak Island provided no evidence for genetically distinct stock structure within the sampled population (Gharrett et al. 2003). The genetic analysis was considered preliminary, and sample sizes were small. Consequently, the lack of evidence for stock structure does not necessarily confirm stock homogeneity. Additional genetic study is needed to verify these results.

9.1.4 Life History, Habitat Utilization, and Diet

Little is known about the life history of northern rockfish. Northern rockfish are presumed to be viviparous with internal fertilization. There have been no studies on fecundity of northern rockfish. Observations during research surveys in the Gulf of Alaska indicate that parturition (larval release) occurs in the spring and is completed by summer. Larval northern rockfish cannot be unequivocally identified to species at this time, even using genetic techniques, so information on larval distribution and length of the larval stage is unknown. The larvae metamorphose to a pelagic juvenile stage, but there is no information on when these juveniles become demersal.

Little information is available on the habitat of juvenile northern rockfish. Studies in the eastern Gulf of Alaska and Southeast Alaska using trawls and submersibles have indicated that several species of juvenile (< 20 cm) red rockfish (*Sebastes spp.*) associate with benthic nearshore living and non-living structure and appear to use the structure as a refuge (Carlson and Haight 1976, Carlson and Straty 1981, Straty 1987, and Kreiger 1993). Freese and Wing (2003) also identified juvenile (5 to 10 cm) red rockfish (*Sebastes sp.*) associated with sponges (primarily *Aphrocallistes sp.)* attached to boulders 50 km offshore in the GOA at 148 m depth over a substrate that was primarily a sand and silt mixture. Only boulders with sponges harbored juvenile rockfish, and the juvenile red rockfish appeared to be using the sponges as shelter (Freese and Wing 2003). These studies did not specifically observe northern rockfish. Length frequencies of northern rockfish captured in NMFS bottom trawl surveys and observed in commercial fishery bottom trawl catches indicate that older juveniles (>20 cm) are found on the continental shelf, generally at locations inshore of the adult habitat (Pers. comm. Dave Clausen).

Trawl surveys and commercial fishing data indicate that the preferred habitat of adult northern rockfish in the Gulf of Alaska is relatively shallow rises or banks on the outer continental shelf at depths of ~75-150 m (Clausen and Heifetz 2003). The highest concentrations of northern rockfish from NMFS trawl survey catches appear to be associated with relatively rough (variously defined as hard, steep, rocky or uneven) bottom on these banks (Clausen and Heifetz 2003). Heifetz (2002) identified rockfish (including *Sebastes spp.*) as among the most common commercial fish captured with gorgonian corals (primarily *Callogorgia, Primnoa, Paragorgia, Fanellia, Thouarella*, and *Arththrogorgia*) in NMFS trawl surveys of Gulf of Alaska and Aleutian waters. Krieger and Wing (2002) identified six rockfish species (*Sebastes spp.*) associated with gorgonian coral (*Primnoa spp.*) from a manned submersible in the eastern Gulf of Alaska. However, neither Heifetz (2002) nor Krieger and Wing (2002) specifically identified northern rockfish in their studies, and more research is required to determine if northern rockfish are associated with living structure, including corals, in the Gulf of Alaska, and the nature of those associations if they exist.

Northern rockfish are generally planktivorous. They eat mainly euphausiids and calanoid copepods in both the GOA and the Aleutian Islands (Yang 1993, 1996, 2003). There is no indication of a shift in diet over time or a difference in diet between the GOA and AI (Yang 1996, 2003). In the Aleutian Islands, calanoid copepods were the most important food of smaller-sized northern rockfish (< 25 cm), while euphausiids were the main food of larger sized fish (> 25 cm) (Yang 1996). The largest size group also consumed myctophids and squids (Yang 2003). Arrow worms, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities (Yang 1993, 1996). Large offshore euphausiids are not directly associated with the bottom, but rather, are thought to be advected onshore near bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes (Brodeur 2001). Predators of northern rockfish are not well documented, but likely include larger fish, such as Pacific halibut, that are known to prey on other rockfish species.

Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for northern rockfish or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. The AFSC has funded a project to the REFM Division to determine if this relationship occurs for Pacific ocean perch in the Central Gulf of Alaska.

9.2 FISHERY

9.2.1 Catch History

A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960's. This fishery developed rapidly with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965 when a total of nearly 350,000 metric tons (mt) was caught, but declined to 45.5 mt by 1976 (Ito 1982). Some northern rockfish were likely taken in this fishery, but there are no available summaries of northern rockfish catches for this period. Foreign catches of all rockfish were often reported simply as "Pacific ocean perch," with no attempt to differentiate species.

Available commercial catch information for slope rockfish in the years since 1977 is listed in Table 9-1. The reader is cautioned that slope rockfish catch data for 1977 - 1987 are for the Pacific ocean perch complex (a former management grouping consisting of Pacific ocean perch and four other rockfish species including northern rockfish), Pacific ocean perch alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 9-1). Actual catches of the slope rockfish in the commercial fishery are only shown for 1988-present.

Foreign fishing dominated the fishery from 1977 to 1984, and slope rockfish catches generally declined during this period. Most of the slope rockfish catch was taken by Japan (Carlson et al. 1986). Catches reached a minimum in 1985, after foreign trawling in the Gulf of Alaska was prohibited.

The domestic fishery for slope rockfish first became important in 1985 and expanded each year until 1991. Much of the expansion of the domestic fishery was apparently related to increasing annual quotas which increased from 3,702 mt in 1986 to 20,000 mt in 1989. In the years 1991-95, overall catches of slope rockfish diminished as a result of the more restrictive management policies enacted during this period. The restrictions included: (1) establishment of the management subgroups, which limited harvest of the more desired species; (2) reduction of levels of total allowable catch (TAC) to promote rebuilding of Pacific ocean perch stocks; and (3) conservative in-season management practices in which fisheries were sometimes closed even though substantial unharvested TAC remained. These closures were necessary because, given the large fishing power of the rockfish trawl fleet, there was substantial risk of exceeding the TAC if the fishery were to remain open.

Total commercial catch (mt) of northern rockfish in the Gulf of Alaska is summarized by foreign, joint venture, and domestic fisheries (Table 9-2). With the advent of a NMFS observer program aboard foreign fishing vessels in 1977, enough information on species composition of rockfish catches was collected so that estimates of the northern rockfish catch were made for 1977-83 from extrapolation of catch compositions from the foreign observer program (Clausen and Heifetz 2002). The relatively large catch estimates for the foreign fishery in 1982-83 are an indication that at least some directed fishing for northern rockfish probably occurred in those years. Joint venture catches of northern rockfish, however, appear to have been relatively modest. A completely domestic trawl fishery for rockfish in the Gulf of Alaska began in 1984, and a domestic observer program was not implemented until 1990. Estimates of the northern rockfish catch were made for 1990-1992 from extrapolation of catch compositions from the domestic observer program (Clausen and Heifetz 2002). Catch estimates of northern rockfish increased greatly from ~1,700 mt in 1990 to nearly 7,800 mt in 1992 (Table 8-2). The increases for 1991 and 1992 can be explained by the removal of Pacific ocean perch and shortraker/rougheye rockfish from the slope rockfish management group. As a result of this removal, relatively low TAC's were adopted for these three species, and the rockfish fleet redirected more of its effort to northern rockfish in 1991 and 1992.

Domestic catches of northern rockfish for years i = {1984, 1985, …, 1989} were estimated for this report by the ratio of domestic northern rockfish catch to domestic slope rockfish catch reported by the 1990 NMFS observer program:

$$\text{northern rockfish catch}_i = \frac{\text{northern rockfish catch}_{1990}}{\text{slope rockfish assemblage catch}_{1990}} * \text{ slope rockfish assemblage catch}_i$$

Northern rockfish were removed from the slope rockfish assemblage and managed with an individual TAC beginning in 1993. As a consequence, directly reported catch for northern rockfish has been available since 1993 (Table 9-1 and Table 9-2). Catch of northern rockfish was reduced after the implementation of a TAC in 1993. Most of the catch since 1993 has been taken in the Central area, where the majority of the northern rockfish exploitable biomass is located. Gulfwide catches for the years 1993-2005 have ranged from 2,947 mt to 5,968 mt, depending on the year. Annual ABC's and TAC's have been relatively consistent during this period and have varied between 4,870 mt and 5,760 mt. Catches of northern rockfish were below their TAC's in 2000 and 2002 as a conservative measure to ensure the TAC was not exceeded. In 2001, catch of northern rockfish was below TAC because the maximum allowable bycatch of Pacific halibut was reached in the central Gulf of Alaska for "deep water trawl species," which includes northern rockfish. Catches of northern rockfish have been near their TAC's in more recent years, 2003 - 2005.

Research catches of northern rockfish have been relatively small and are listed in Table 9-3.

9.2.2 Description of the Fishery

In the Gulf of Alaska, northern rockfish are generally caught with bottom trawls identical to those used in the Pacific ocean perch fishery. Many of these nets are equipped with so-called "tire gear," in which automobile tires are attached to the footrope to facilitate towing over rough substrates. Most of the catch has been taken during July, as the directed rockfish trawl fishery in the Gulf of Alaska has traditionally opened around July 1. Rockfish trawlers usually direct their efforts first toward Pacific ocean perch because of its higher value relative to other rockfish species. After the TAC for Pacific ocean perch has been reached and NMFS closes directed fishing for this species, trawlers switch and target northern rockfish.

Historically, bottom trawls have accounted for nearly all the commercial harvest of northern rockfish in the Gulf of Alaska. In the years 1990-98, bottom trawls took over 99% of the catch (Clausen and Heifetz 2002). Before 1996, most of the slope rockfish trawl catch (>90%) was taken by large factory-trawlers that processed the fish at sea. A significant change occurred in 1996, however, when smaller shore-based trawlers began taking a sizeable portion of the catch in the Central Gulf for delivery to processing plants in Kodiak. Factory trawlers continued to take nearly all the northern rockfish catch in the Western area during this period. The following table shows the percent of the total catch of northern rockfish in the Central area that shore-based trawlers have taken since 1996.[1]

Percent of catch taken by shore-based trawlers in the Central Gulf area

	1996	1997	1998	1999	2000	2001	2002
Northern rockfish	32	32	53	44	73	57	73

9.2.3 Localized Depletion

A study of the northern rockfish fishery for the period 1990-98 showed that 89% of northern rockfish catch was taken from just five relatively small fishing grounds: Portlock Bank, Albatross Bank, an unnamed bank south of Kodiak Island that fishermen commonly refer to as the "Snakehead," Shumagin Bank, and Davidson Bank (Clausen and Heifetz 2002). In particular, the Snakehead accounted for 46% of the northern rockfish catch during these years. All of these grounds can be characterized as relatively shallow (75–150 m) offshore banks on the outer continental shelf.

Results of an analysis of localized depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium. Results of the depletion study indicated that targeted hauls for some slope

[1]National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 5, 2002.

rockfish species in the Gulf of Alaska showed a short term decline (a period of weeks) in CPUE during the fishing season and a rebound in CPUE by the next year. These results suggest that there is evidence of short term localized depletion for some slope rockfish species in the Gulf of Alaska, but depletion is not serial (i.e. the stock rebounded from year to year). One exception was that year-over-year localized depletion occurred in northern rockfish CPUE in the "Snakehead" area of the Gulf of Alaska. Significant depletion in northern rockfish CPUE was detected in one year (1994) over a period of a few weeks. Following 1994, fishery and survey CPUE did not rebound, indicating year-over-year localized depletion. Some depletion of dusky rockfish appeared to occur in the same area and year, but the depletion was not as severe. The "Snakehead" was fished heavily for northern rockfish in the 1990's, but is now only lightly fished. The change in fishery effort may have been due this depletion event in the 1990s. A publication is in preparation for the proceedings.

9.2.4 Bycatch

Data from the observer program for 1990-98 indicated that 82% of the northern rockfish catch during that period came from directed fishing for northern rockfish and 18% was taken as bycatch in fisheries for other species (Clausen and Heifetz 2002).

The only detailed analysis of bycatch in slope rockfish fisheries of the Gulf of Alaska is that of Ackley and Heifetz (2001) who examined data from the observer program for the years 1993-95. For hauls targeting on northern rockfish, the predominant bycatch species was dusky rockfish, distantly followed by "other slope rockfish," Pacific ocean perch, and arrowtooth flounder.

9.2.5 Discards

Gulfwide discard rates[2] (% discarded) for northern rockfish in the commercial fishery for 1993-2002 are as follows:

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
26.5	17.7	12.7	16.5	27.8	18.3	11.1	8.7	17.5	9.8

These discard rates are generally similar to those in the Gulf of Alaska for Pacific ocean perch and slightly higher than those for dusky rockfish.

9.3 DATA

The model was updated to include the 2005 survey biomass estimate, updated catch from 2004, preliminary catch for 2005, survey age composition from 2003, new fishery age compositions from 2003 and 2004, and updated fishery age compositions from a backlog of available otoliths for the years 2000 – 2002. Fishery length compositions were removed for the years 1998-2003 because fishery age compositions were utilized for these years.

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1977-2005
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
NMFS bottom trawl surveys	Age compos.	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003
U.S. trawl fisheries	Age compos.	1998, 1999, 2000, 2001, 2002, 2003, 2004
U.S. trawl fisheries	Length compos.	1990,1991,1992, 1993, 1994, 1995, 1996, 1997

2 Source: National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21688, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 5, 2002.

9.3.1 Fishery Data

9.3.1.1 Catch

Catch information for northern rockfish is listed in Table 9-2.

9.3.1.2 Age and Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age compositions of the commercial catch of northern rockfish. Table 9-4 and Figure 9-1 summarize the length compositions, and Table 9-5 and Figure 9-2 summarize the age compositions. The fishery length compositions indicate the recent recruitment of smaller fish to the population during the years 2002 and 2003 (Figure 9-1). The fishery age compositions indicate that strong yearclasses occurred around the years 1976 and 1984 (Figure 9-2). The fishery age composition from 2004 also indicates that 1994 is emerging as a strong yearclass. The sample size (942) for the at sea fishery age composition data in 2004 appears to be large enough to adequately resolve recent yearclasses (Figure 9-2). The clustering of several large yearclasses in each period is most likely due to aging error.

9.3.2 Survey Data

9.3.2.1 Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999, and these surveys became biennial in 2001, 2003, and 2005. The surveys provide an index of abundance (biomass), size and age composition data, and growth characteristics. The trawl surveys have used a stratified random design to sample fishing stations that cover all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 1,000 m). Generally, attempts have been made through the years to standardize the survey design and the fishing nets used, but there have been some exceptions to this standardization. In particular, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed in this report, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 introduced an element of uncertainty as to the standardization of these two surveys. Also, a different survey design was used in the eastern Gulf of Alaska in 1984, and the eastern Gulf of Alaska was not covered by the 2001 survey. These data inconsistencies for the eastern Gulf of Alaska have had little effect on the survey results for northern rockfish, as relative abundance of northern rockfish is very low in the eastern Gulf of Alaska.

The biomass estimates for northern rockfish have been highly variable from survey to survey (Table 9-6 and Figure 9-3). In particular, the 2005 Gulfwide survey biomass estimate (359,026 mt) was 82% higher than the 2003 biomass estimate (66,368 mt). The 2003 survey biomass estimate (66,368 mt) was 18% of the 2001 biomass estimate (355,275 mt). Such large fluctuations in biomass do not seem reasonable given the long life, slow growth, and low natural mortality of northern rockfish.

The variance of individual biomass estimates has also been high and is reflected in the large 95% confidence intervals associated with recent survey biomass estimates of northern rockfish (Table 9-6 and Figures 9-3, and 9-20). In both 1999 and 2001, a single very large survey haul of northern rockfish greatly increased the biomass estimates and resulting estimate of biomass variance. The haul in 2001 was the largest individual catch (14 mt) of northern rockfish ever taken during a Gulf of Alaska survey. In contrast, the 2005 survey had several large hauls of northern rockfish in the Central Gulf and the variance estimate was relatively smaller (Table 9-6). The highly variable biomass estimates for northern rockfish suggest that the stratified random design of the surveys does a relatively poor job of assessing stock condition of northern rockfish and that a different survey approach may be needed to reduce the variability in biomass estimates.

9.3.2.2 Survey Size Compositions
The Gulf of Alaska trawl surveys provide size composition data for northern rockfish population. Generally, the northern rockfish size compositions have been unimodal and provide no indication of recruitment of smaller fish. Estimated mean length of the population increased from 34.7 cm in 1990 to 37.8 cm in 1999, and then decreased slightly to ~37 cm in 2001 and 2003. Survey size composition estimates are not used directly in the current age structured assessment model but are used to expand the length stratified survey age compositions to random samples of survey age composition for use in the model.

9.3.2.3 Survey Age Compositions
The Gulf of Alaska trawl surveys provide age composition data for northern rockfish by extrapolating the length stratified survey age frequencies obtained from break and burn otolith readings through the randomly collected survey length compositions. Survey age compositions for the Gulfwide northern rockfish population are available for 1984, 1987, 1990, 1993, 1996, 1999, 2001, and 2003 (Table 9-7 and Figure 9-4). The age compositions from each survey indicate that recruitment of northern rockfish is highly variable. Several surveys (1984, 1987, 1990, and 1996) show especially strong yearclasses from the period around 1975-77, although they differ as to which specific years were greatest, perhaps due to aging errors. The 1993, 1996, and 1999 age compositions also indicate that the 1983-85 yearclasses may be stronger than average, which is in agreement with recent age compositions obtained from the commercial fishery described above. The survey age composition from 2003 also indicates that 1994 is emerging as a strong year class (Figure 9-4). Mean age of northern rockfish in the surveys has increased from 13.1 years in 1984 to 18.6 years in 1999 and come down slightly to 18.15 years in 2001.

9.4 ANALYTIC APPROACH

Gulf of Alaska northern rockfish are currently assessed using an age structured modeling approach. Model development was described in detail in an earlier SAFE appendix (Courtney et al. 1999). The model structure was refined for application to other rockfish species managed by the AFSC at a 2001 rockfish modeling workshop and resulted in an age structured model template for applications to rockfish species managed by the AFSC.

9.4.1 Model Structure

Model 1 through Model 5 utilized the same age-structured rockfish model template as used in the last full assessment for northern rockfish (Courtney et al 2003). The rockfish model template was constructed with AD Model Builder software (Otter Research Ltd 2000) and performs population analysis on sequential catch-at-age data with an allowance for catch-at-length data where age data are missing (Box 1). Model 1 also incorporated a Beverton Holt spawner-recruit relationship and estimated parameters for B_0, R_0 and h (Courtney et al. 1999). B_0 and R_0 can be thought of as equilibrium biomass and recruitment, respectively. An error term was incorporated to estimate deviations around equilibrium rectuitment for the initial age structure. The parameter "h" can be interpreted as the "steepness" of the stock-recruit relationship, or the speed at which the spawner-recruit curve reaches the maximum or asymptote.

The AD Model Builder structure utilizes a penalized maximum likelihood framework to estimate desired management quantities. Separability of the exploitation fraction was assumed between age-dependent gear selectivity and the time-dependent exploitation fraction for fully recruited fish. Auxiliary information was added in the form of survey indices of biomass in order for catch-at-age analysis to accurately scale the population estimates. A parameter for survey catchability, q, was estimated which allowed survey biomass estimates to be treated as an index of abundance. Natural mortality, *M*, can be estimated from within the model or supplied as a fixed value. Models 1 and 4 fixed *M* at an independently estimated value (0.06). Models 3 and 5 estimated *M* from within the model with an informative lognormal prior. The model accommodates either single selectivity or separate fishery and survey selectivities. Model 1 estimated a single selectivity for both the fishery and the survey. Models 2 through 5 estimated separate selectivities for the fishery and the survey. Log parameters were estimated for reliability in the estimation process (Kimura 1989, 1990).

Error in the predicted catch is allowed by including a weighting factor in the catch data likelihood. Similarly, weighting factors are included for the multinomial likelihoods due to age and length compositions according to confidence in the data set. A measure of sample size is also required within the age and length likelihoods. Models 1 through 5 use the number of hauls scaled to a maximum of 100 as sample sizes within the age and length likelihoods. The survey abundance index likelihood was fixed at one, and the standard errors of biomass estimates were used as a measure of sample size within the likelihood.

Penalties were added to the overall objective function in order to constrain parameter estimates to reasonable values and to speed model convergence. A functional form was not given to selectivity. Instead, selectivity deviations were penalized by allowing selectivity to vary as a smooth function of age up to the first fully selected age, and then by minimizing the degree of dome shape after the fully selected age. Fishing mortality regularity was penalized by minimizing the residuals of year to year mortality fluctuations. Recruitment irregularity was penalized by adding a likelihood due to recruitment deviations and estimating an additional parameter for recruitment variability (σ_r) from within the model. The likelihood component due to recruitment deviations was fixed at one.

Parameter estimates for the key parameters of survey catchability (*q*), natural mortality (*M*), and recruitment variability (σ_r) were constrained within the overall objective function by minimizing deviations from assumed lognormal prior distributions. Means and standard errors (μ,σ) for the lognormal distributions were provided as input to the model and were based upon prior biological knowledge and evaluated with MCMC posterior distributions from model runs designed to test model sensitivity and uncertainty to these key parameters.

9.4.2 Model Uncertainty

AD Model Builder software has an option to automatically compute an estimate of the standard error of any estimated or conditional model parameter from the inverse of the covariance matrix (Hessian matrix). AD Model Builder software also has an optional extension to automatically estimate the Bayesian posterior distribution for any estimated or conditional model parameter. We used standard errors and 95% confidence intervals derived from both the Hessian matrix and MCMC to evaluate model uncertainty. In our MCMC simulations, we removed the first 500,000 “burn-in” iterations out of 5,000,000 and “thinned” the chain to one value out of every thousand, leaving a sample distribution of 4,500. Further assurance that the chain had converged was obtained by comparing the mean of the first half of the chain with mean of the second half after removing the “burn-in” and “thinning.” If these two values were similar, then we concluded that convergence had been attained (Gelman et al. 1995). Results are shown for key parameters.

9.5 ASSESSMENT PARAMETERS

9.5.1 Parameters Estimated Independently

The natural mortality rate (*M*) for northern rockfish in the Gulf of Alaska is estimated to be 0.06. This estimate was determined by Heifetz and Clausen (1991) using the method of Alverson and Carney (1975). Maximum reported age for northern rockfish is 67 years in the Gulf of Alaska (2002 fishery age composition) and 72 in the Aleutian Islands (Malecha and Heifetz 2000). Age at first recruitment to the commercial fishery is 4 years and to the survey is 2 years (Tables 9-5 and 9-7).

Area	Mortality rate	Maximum age	Age of first recruitment
Gulf of Alaska	0.06*	67	2 – 4
Aleutians	-	72	-

* Used in this assessment.

Age at 50% maturity (13 years) and size at 50% maturity (36.1 cm fork length) for northern rockfish in the Gulf of Alaska was estimated from a sample of 77 females in the central Gulf of Alaska[3].

Area	Size at 50% maturity	Age at 50% maturity	Sample size
Central Gulf of Alaska	36.1	12.8*	77

* Used in this assessment.

Length-weight coefficients for the formula $W=aL^b$, where W = weight in grams and L = length in mm, are from Heifetz and Clausen (1989), Martin (1997), and Courtney et al. (1999).

Area	Sex	a	b	Year
GOA	combined	1.63 x 10-5	2.98	1989
GOA	combined	1.37 x 10-5	3.04	1997
GOA	males	1.55 x 10-5	2.99	1997
GOA	females	1.53 x 10-5	3.01	1997
GOA	combined	1.75 x 10-5	2.98	1999*

* Used in this assessment.

The von Bertalanffy growth parameters for northern rockfish in the Gulf of Alaska are from Heifetz and Clausen (1991), Courtney et al. (1999), and Malecha and Heifetz (2000).

Area	Sex	t0	k	Linf (cm)	Year
GOA	combined	-1.51	0.190	35.60	1991
GOA	combined	-0.76	0.170	38.30	1999*
GOA	combined	-0.64	0.165	39.16	2001
GOA	male	-0.26	0.187	37.83	2001
GOA	female	-0.87	0.152	40.22	2001
AL	combined	-7.16	0.103	34.27	2001
* Used in current assessment.					

* Used in this assessment.

9.5.2 Length-at-age and Aging Error Transition Matrices

A length-at-age transition matrix was constructed by adding normal error to the von Bertalanffy growth curve with standard deviation of length modeled as a linearly increasing function of age (Courtney et al. 1999). An aging error matrix was constructed by assuming that break and burn ages were unbiased with a normal error around each age (Courtney et al. 1999).

9.5.3 Parameters Estimated Conditionally

Parameters estimated conditionally include but are not limited to: catchability (q), selectivity (up to full selectivity) for survey and fishery, recruitment deviations, mean recruitment, fishing mortality, and spawners per recruit levels (Box 1).

[3]C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801. Pers. Comm. July, 1997.

BOX 1. AD Model Builder Rockfish Model Template Description

Parameter	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q	Survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
q_{prior}	Prior mean for catchability coefficient
M_{prior}	Prior natural mortlatity
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ_q^2	Prior CV for catchability coefficient
σ_M^2	Prior CV for natural mortlatiy
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_y = q \; * \sum_a N_{y,a} * \frac{s_a}{\max\left(s_a\right)} * w_a$$

Survey biomass index (mt)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr - a_o - a - 1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr - a_o - a - 1}\right)} e^{-(a - a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{\left(\mu_r\right)} e^{-(a - a_0)M}}{\left(1 - e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y \right)^2}{2 * \hat{\sigma}^2 \left(I_y \right)}$	Survey biomass index likelihood
$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001 \right) * \ln\left(\hat{P}_{y,a} + 0.001 \right)$	Fishery age composition likelihood ($n^*{}_y$ =sample length, standardized to maximum of 100)
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln\left(\hat{P}_{y,l} + 0.001 \right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001 \right) * \ln\left(\hat{P}_{y,a} + 0.001 \right)$	Survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln\left(\hat{P}_{y,l} + 0.001 \right)$	Survey length composition likelihood
$L_7 = \frac{1}{2\sigma_q^2} \left(\ln\left(q \big/ q_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_8 = \frac{1}{2\sigma_M^2} \left(\ln\left(M \big/ M_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln\left(\sigma_r \big/ \sigma_{r(prior)} \right) \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{10} = \lambda_{10} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r \right) \right]$	Penalty on recruitment deviations
$L_{11} = \lambda_{11} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{12} = \lambda_{12} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{13} = \lambda_{13} \sum_{a_0}^{a_+} \left(s_i - s_{i+1} \right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{14} = \lambda_{14} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1}) \right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences
$L_{total} = \sum_{i=1}^{14} L_i$	Total objective function value

9.6 MODEL ALTERNATIVES

Summary of model alternatives

Model 1	Model 2	Model 3	Model 4	Model 5
BaseCase 2003 Updated data	Model 1 but separate Fish and Surv selectivities	Model 2 with M estimated	Model 2 with historic F	Model 4 with M estimated

9.6.1 Base Model (Model 1)

The base model (Model 1) for this year's stock assessment for northern rockfish is the same age structured model used in last year's stock assessment except that Model 1 removed fishery length compositions for years with fishery age compositions (1998-2004). The model differs from the rockfish template described in Box 1 by the addition of a stock recruit relationship with a prior for steepness (Courtney et al. 1999).

9.6.2 Alternative Case (Model 2)

In 2003, we explored the use of an alternative model (Model 2, Courtney et al. 2003) which we explored again this year. Model 2 is identical to the age structured model used in the 2003 POP assessment (Hanselman et al. 2003). The main difference between Model 1 and Model 2 was that Model 2 estimated separate survey and fishery selectivities. The maximum age for survey selectivity was reduced from age 11 to age 8. The choice of age 8 was based upon POP model results. Model sensitivity to the choice of age 8 was not examined.

Model 2 also set all data likelihood weights except that for catch to one, relaxed the selectivity penalties, and relaxed fishing mortality penalties. Fits to the data were achieved in Model 2 by incorporating a more informative lognormal prior (μ,σ) of 1.7 and 0.002 on recruitment variability (σ_r), which allowed for high recruitment variability without forcing excessive weights on data likelihood components.

Model 2 also removed the spawner recruit relationship, and reformulated the fishing mortality regularity penalty. Reformulation of the fishing mortality regularity penalty (northern rockfish alternative Model 5, Heifetz et al. 2001) and the removal of the spawner recruit relationship (northern rockfish alternative northern rockfish alternative Model 3, Heifetz et al. 2001) had little effect on model results (Heifetz et al. 2001) and were not examined again here.

9.6.3 Alternative Case (Models 3)

Model 3 estimated natural mortality (*M*) from within the model with an informative lognormal prior.

9.6.4 Alternative Case (Models 4 and 5)

As indicated in section 9.2.1 northern rockfish were probably caught in the foreign Pacific ocean perch trawl fishery during the early 1960's. To allow for historic fishing pressure, a parameter for historical fishing mortality (F Historic) was incorporated in computations of initial numbers at age in 1977, and estimated on the log scale. Two additional model alternatives resulted. Model 4 modified Model 2 to estimate historical fishing mortality in computations of initial numbers at age in 1977. Model 5 modified Model 3 to allow for both the estimation of natural mortality with an informative lognormal prior, and the estimation of historical fishing mortality in computations of initial numbers at age in 1977.

9.7 MODEL EVALUATION

Model fits to data are provided as unweighted maximum likelihood values for applications of Models 1 through 5 (Table 9-8). Weighting factors for selected likelihood components along with prior distributions for natural mortality (M), trawl survey catchability (q), steepness (h), and recruitment variability (σ_r) are listed in Table 9-8. Maximum likelihood estimates (MLE) are provided for selected parameters along with standard errors (σ) derived from the Hessian matrix and standard errors (σMCMC) and Bayesian 95% confidence intervals (BCI) derived from MCMC (Table 9-9). Model results for Models 1 through 5 are in listed in Table 9-10. Results for Model 1 and Model 5 are shown in Figures 9-5 and 9-6. Model 1 and Model 5 fits to age and length data are provided in Figures 9-12 through 9-17. Plots of fully selected fishing mortalities for a model with (Model 4) and without (Model 2) historic fishing mortality are in Figure 9-18.

9.7.1 Model 1

The effect of removing fishery size compositions from the model for years 1998-2003 (years with age compositions) was not examined. Steepness is not well estimated. The posterior distribution of steepness was not normally distributed and the maximum likelihood estimate of 1.0 was at the upper bound of the parameter (1) (Figure 9-9, Table 9-9).

The parameter σ_r is designed to reflect process error (i.e unexplained variability in estimation of recruitment deviations from sources other than stock size) and is contingent upon good age data. We allow estimation of σ_r with an assumed lognormal prior distribution. A value of recruitment variability (σ_r) near 0.88 is sufficient to allow estimation of recruitment deviations.

MCMC and Hessian 95% confidence intervals for biomass, spawning biomass, and recruitment from Model 1 are shown in Figure 9-7. MCMC 95% confidence intervals were large relative to MLE estimates indicating that the estimates were highly uncertain. Hessian matrix 95% confidence intervals and Maximum Likelihood Estimates of total biomass, spawning biomass, and recruitment were negatively biased relative to the MCMC 95% confidence intervals. A positive skew of predicted values is expected in a lognormally distributed parameter. However, these results could also indicate that biomass is underestimated in Model 1.

9.7.2 Model 2

The total objective function (unweighted) was smaller for Model 2 than for Model 1. Model 2 was able to achieve a comparable fit to the data as Model 1, with smaller weighting terms on several likelihood components. Model 2 fit the age data by incorporating a more informative lognormal prior on recruitment variability (μ,σ) of 1.7 and 0.002, respectively (Table 9-8). The value 1.7 was near the mode of the posterior distribution of recruitment variability for Models 1 – 5 (Figure 9-9). Survey catchability (q) was higher in Model 2 (0.8), than in Model 1(0.54) and projected ABC for 2006 was smaller for Model 2 (3,582 mt) than for Model 1 (3,964 mt) (Tables 9-9 and 9-10). These ABC's were both less than the recommended ABC from the 2003 (4,874 mt, Courtney et al. 2003) and were unexpected given the high 2005 biomass estimate (Figure 9-3).

9.7.3 Models 3 and 4

Models 3 and 4 are intermediate steps between Model 2 and Model 5. Results from Models 3 and 4 are shown in Tables 9-8 through 9-10, and Figures 9-9 through 9-11.

9.7.4 Model 5

Estimated natural mortality from Model 5 (0.056, CV-MCMC 10%, Table 9-9) was similar to that obtained from an independent estimate (0.06) (Heifetz and Clausen 1999). Estimated historical F (0.08) from Model 5 was uncertain with a very wide 95% MCMC confidence interval (0.0003, 0.2215) (Table 9-9, Figure 9-11).

The main affect of estimating historical F was a reduction in the number of older age fish in the initial year (1977, Figure 9-6), lower estimates fully selected fishing mortality in later years (Figure 9-18), a higher estimate of log mean recruitment (Models 4 and 5, Figure 9-10), proportionally higher recruitment in 1978 and 1996 relative to Model 1 (Figures 9-5 and 9-6), and higher projected ABC in 2006 (Table 9-10). Model 5 also had a slightly better fit to the 2005 survey biomass estimate than Model 1 (Figures 9-5 and 9-6).

Recent trends in total biomass from Model 5 are increasing, while recent trends in spawning biomass are slightly decreasing (Figures 9-6 and 9-8). These trends are expected if recent strong recruitment in 1996 (1994 yearclass) and beyond is not yet fully mature (age at 50% maturity 13 years). A period of recent relatively high fishing mortality also began in the early 1990s which may explain the change in trajectory of biomass and spawning biomass around this time (Figures 9-5 and 9-6).

MCMC and Hessian 95 % confidence intervals for biomass, spawning biomass, and recruitment from Model 5 are shown in Figure 9-8. MCMC and Hessian matrix 95% confidence intervals were large for total biomass, spawning biomass and recruitment, but les negatively biased than Model 1 (Figure 9-7). There was also more uncertainty in recent years from Model 5 than from Model 1, which is expected because these years have less data in the model.

9.8 MODEL RESULTS

Model 5 is recommended for this year's assessment. Model 5 had the best fit to increased biomass from the 2005 NMFS bottom trawl survey and had the best overall fit to the data (lowest overall unweighted objective function).

Fits of Model 5 to fishery age compositions, survey age compositions, and fishery size compositions are shown in Figures 9-15, 9-16, and 9-17 along with comparisons of Model 1 fits to data in Figures 9-12, 9-13, and 9-14. Model 5 time series of female spawning biomass, total biomass (6 +), catch /(6+ total biomass), and the number of age-2 recruits are shown in Table 9-11. Model 5 estimates of numbers at age in 2006, fishery and survey selectivity, maturity-at-age (estimated independently), and weight-at-age are shown in Table 9-12.

The number of age-2 recruits in 2006 is estimated as the average recruitment from the 1977 through 1999 yearclasses (19,917, Table 9-11). Projected female spawning biomass in 2006 is 36,199 mt, projected exploitable biomass in 2006 is 99,554 mt, and projected age 6+ total biomass is 122,591 mt (Table 9-11).

Model 5 estimates suggest a current population dominated by older fish from three strong yearclasses (1968-1970, 1975-1977, and 1982-1984, Figures 9-2 and 9-4). The spread in these strong yearclasses is likely due to aging error. Spawning biomass of the strong 1976 yearclass peaked in the early 1990's and has been slowly dropping as this yearclass dies off (Figures 9-6 and 9-8). Trends in total biomass from Model 5 are increasing as a result of recent high recruitment in 1996 (1994 yearclass) and beyond (Figures 9-6 and 9-8). The 1994 yearclass (recruited in1996) has continued to emerge as a larger than average yearclass and is now estimated to be of the same magnitude as the large 1976 yearclass (recruited 1978, Figures 9-6 and 9-8), but with a higher degree of uncertainty (Figure 9-8). Smaller fish now make up a relatively large proportion of recent fishery size compositions (Figure 9-1), which is likely the result of the strong 1994 yearclass.

9.9 PROJECTIONS AND HARVEST ALTERNATIVES

9.9.1 Harvest Alternatives (Model 5)

Based on this year's recommended assessment model (Model 5), the projected female spawning biomass in 2006 B_{2006} is 36,199 mt (Table 9-10). $B_{40\%}$, determined from average recruitment of the 1977-1999 year-classes (recruits from years 1979 – 2001) is 29,559 mt (Tables 9-10 and 9-13). Since B_{2006} is greater than $B_{40\%}$, the computation in Tier 3a [i.e., F_{ABC} ◂ $F_{40\%}$] is used to determine the maximum value of F_{ABC}. As in last year's assessment, we recommend that $F_{40\%}$ be used as the basis for ABC calculations. We recommend that the ABC for northern rockfish for the 2006 fishery in the Gulf of Alaska be set at 5,891 mt.

2003 was the last year with a full assessment. Projected spawning biomass (B_{2006}, 36,199 mt, Table 9-10) from this year's assessment is slightly smaller than projected spawning biomass (B_{2003}, 36,482, Courtney et al 2003) from the 2003 assessment. Equilibrium spawning biomass ($B_{40\%}$ 29,559 mt), and recommended ABC for 2006 from this year's assessment are higher than equilibrium spawning biomass ($B_{40\%}$, 23,929, Courtney et al, 2003), and recommended ABC for 2003 (4,874 mt, Courtney et al, 2003) from the 2003 assessment.

The 1994 yearclass is emerging as stronger than average. This strong recruitment, along with recent high survey biomass estimates, supports an increase in ABC. However, there is uncertainty in the recent biomass estimates, and evidence of localized depletion, consequently, caution is warranted for management of this stock.

9.9.2 Projections

For northern rockfish, projected B_{2006} (36,199 mt) is greater than $B_{35\%}$ (25,864 mt), and by the definitions below, the stock is not overfished (Tables 9-10 and 9-13). In addition, B_{2008} (36,361 mt) is greater than $B_{35\%,}$ and by the definitions below, the stock is not approaching an overfished condition (Table 9-13).

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3. This set of projections encompasses seven harvest scenarios and is designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2005 numbers at age from the recommended model. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2005. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2006, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TAC's.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the *max* F_{ABC} for 2006. (Rationale: When F_{ABC} is set at a value below max F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use pre-specified catch for 2006 (5,702 mt) to provide a more accurate short-term projection of spawning biomass and ABC for species where much of the ABC goes unharvested.

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the most recent five year (2001- 2005) average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. This scenario determines whether a stock is overfished.

Scenario 7: In the first two years (2006 and 2007), F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. This scenario determines whether a stock is approaching an overfished condition.

9.9.3 Projections and Status Determination

Harvest scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined as overfished. Any stock that is expected to fall below its MSST in the next two years is defined as approaching an overfished condition. Harvest scenarios #6 and #7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2006:

a) If spawning biomass for 2006 is estimated to be below ½ B35%, the stock is below its MSST.

b) If spawning biomass for 2006 is estimated to be above B35%, the stock is above its MSST.

c) If spawning biomass for 2006 is estimated to be above ½ B35% but below B35%, the stock's status relative to MSST is determined by referring to harvest scenario #6 ("Overfished," Table 9-13). If the mean spawning biomass for 2018 is below B35%, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest scenario #7 ("Approaching overfished," Table 9-13):

a) If the mean spawning biomass for 2008 is below ½ B35%, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2008 is above B35%, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2008 is above ½ B35% but below B35%, the determination depends on the mean spawning biomass for 2018 ("Approaching overfished" Table 9-13). If the mean spawning biomass for 2018 is below B35%, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

9.9.4 Apportionment of ABC

The 2006 area apportionments for Gulf of Alaska northern rockfish are 29.12% for the Western area, 70.84% for the Central area, and 0.04% for the Eastern area. Applying these apportionments to the recommended ABC for northern rockfish results in 1,706 mt for the Western area, 4,149 mt for the Central area, and 3 mt for the Eastern area. For management purposes, the small ABC of northern rockfish in the Eastern area is combined with other slope rockfish.

Prior to the 1996 fishery, the apportionment of ABC among areas was determined from distribution of biomass based on the average proportion of exploitable biomass by area in the most recent three triennial trawl surveys. For the 1996 fishery, an alternative method of apportionment was recommended by the Plan Team and accepted by the Council. Recognizing the uncertainty in estimation of biomass yet wanting to adapt to current information, the Plan Team chose to employ a method of weighting prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass, the weight of a prior survey should be 2/3 the weight of the preceding survey. This results in weights of 4:6:9 for the 2001, 2003, and 2005 surveys, respectively. Exploitable survey biomass is calculated as survey biomass for depths greater than 100 m. The percentage of exploitable survey biomass by area is averaged rather than the raw values. The eastern Gulf was not covered by the 2001 trawl survey. The 2001 Eastern Gulf exploitable survey biomass estimate is the average of 1993, 1996, and 1999 Eastern Gulf exploitable survey biomass estimates.

Percentage of survey biomass by region and resulting area apportionments follow:

Percentage of exploitable survey biomass estimates by Gulf of Alaska region			
	Western	Central	Eastern
2001 - Northern rockfish	26.18%	73.79%	0.03%
2003 - Northern rockfish	13.005%	86.973%	0.022%
2005 - Northern rockfish	41.2%	58.8%	0.1%
Apportionment (4:6:9) weighted average of 2001, 2003,2005 percent exploitable biomass			
	Western	Central	Eastern
Apportionment - Northern rockfish	29.12%	70.84%	0.04%

*bold values are proportions based on average of 93,96, 99 Eastern Gulf values

9.9.5 Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.080), overfishing is set equal to 7,033 mt for Gulf of Alaska northern rockfish. The overfishing level is not apportioned by area for Gulf of Alaska northern rockfish.

9.10 Summary

A summary of biomass levels, exploitation rates and recommended ABCs and OFL's for northern rockfish from Models 1-5 are given in Table 9-10. 6+ total biomass is for age 6 and greater fish projected from the age-structured models for 2006 (Table 9-11). Biomass in 2006 is female spawning biomass (Table 9-10).

Model 5 is recommended for this year's assessment. Model 5 had the best fit to increased biomass from the 2005 NMFS bottom trawl survey and had the best overall fit to the data (lowest overall unweighted objective function). Based on Model 5, the recommended ABC for 2006 is 5,857 mt. The corresponding reference values for northern rockfish recommended for this year and projected one additional year are summarized below:

SAFE 2005 for 2006	Last Year's 2004 Interim Assessment for 2005 Projected with Updated Catch		This Year's 2005 Full Assessment for 2006, Projected for 2007 with Catch at $F_{40\%}$	
Summary	2005	2006	2006[1]	2007[2]
6+ Total Biomass (mt)	88,953	83,485	122,591	120,280
$B_{40\%}$ (mt)	24,693	24,693	29,559	29,559
Female spawning biomass (mt)	38,272	36,108	36,199	35,988
$F_{50\%}$	0.040	0.040	0.046	0.046
Projected Yield at $F_{50\%}$	3,623	3,378	4,333	4,244
$F_{40\%}$	0.057	0.057	0.062	0.062
F_{ABC} (max. $F_{40\%}$)	0.057	0.057	0.062	0.062
ABC (mt, max perm.)	5,093	4,749	5,857	5,802
F_{OFL} ($F_{35\%}$)	0.068	0.068	0.075	0.075
OFL (mt, $F_{35\%}$)	6,050	5,642	7,033	7,277

[1]Recommended for ABC

[2] The 2007 ABC and OFL were projected using an expected catch value of 5.702 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author's F method was used for this projection (Table 9-13) in response to management requests for a more accurate one-year projection.

9.11 ECOSYSTEM CONSIDERATIONS

In general, a determination of ecosystem considerations for northern rockfish is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 9-14.

9.11.1 Ecosystem Effects on the Stock

Prey availability/abundance trends: Similar to many other rockfish species, stock condition of northern rockfish appears to be influenced by periodic abundant yearclasses. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval northern rockfish may be an important determining factor of yearclass strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and yearclass strength. Moreover, identification to the species level for field collected larval northern rockfish is difficult. Visual identification is not possible, though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et al. 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult northern rockfish feed on euphausiids. Euphausiids are also a major item in the diet of walleye pollock. Changes in the abundance of walleye pollock could lead to a corollary change in the availability of euphausiids, which would then have an impact on northern rockfish.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent by marine mammals during late juvenile and adult stages. Whether or not the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile northern rockfish, but information on these life stages and their predators is not available.

Changes in physical environment: Strong yearclasses corresponding to the period around 1977 have been reported for many species of groundfish in the Gulf of Alaska, including northern rockfish. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including northern rockfish. Northern rockfish appear to have had a strong 1984 yearclass. There may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effects on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions.

9.11.2 Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for pollock, deepwater flatfish, and Pacific ocean perch account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones, sea whips, and sea pens. The bottom trawl fisheries for Pacific ocean perch and Pacific cod and the pot fishery for Pacific cod account for most of the observed bycatch of sponges (Table 9-15).

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The directed slope rockfish trawl fishery that begins in July is concentrated in known areas of abundance and typically lasts only a few weeks. The annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery.

Fishery-specific effects on amount of large size target fish: No evidence for targeting large fish.

Fishery contribution to discards and offal production: Fishery discard rates of slope rockfish during 2000-2002 have been 9-18% for northern rockfish. The discard amount of species other than slope rockfish in the slope rockfish fishery has not been determined.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Unknown.

Fishery-specific effects on EFH non-living substrate: Unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can move around rocks and boulders on the bottom.

9.12 DATA GAPS AND RESEARCH PRIORITIES

9.12.1 Life History and Habitat Utilization

There is little information on larval, post-larval, or early life history stages of northern rockfish. Habitat requirements for larval, post-larval, and early stages mostly unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling may have on these biota.

Results of an analysis of localized depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium. The use of Leslie depletion estimators on targeted rockfish catches detected relatively few localized depletions for northern rockfish. Several significant depletions occurred in the early 1990s for northern rockfish, but were not detected again by the depletion analysis. However, when fishery and survey CPUEs were plotted over time for a block of high rockfish fishing intensity that contained the "Snakehead," the results indicated there were year-over-year drops in both fishery and survey CPUE for northern rockfish. Presently, fishing for northern rockfish is nearly absent relative to previous effort in the area. The significance of these observations depend on the migratory and stock structure patterns of northern rockfish. If fine-scale stock structure is determined in northern rockfish, or if the area is essential to northern rockfish reproductive success, then these results would suggest that current apportionment of ABC may not be sufficient to protect northern rockfish from localized depletion.

Under current management, the fishing season for slope rockfish in the Gulf of Alaska has been relatively short-lasting only a few weeks in July each year, which tends to concentrate the fishery in time and space. A pilot Gulf of Alaska rockfish rationalization fishery is planned for 2006. If the fishing season is extended under Gulf Rationalization pilot project, then the fishery may spread out in time and space and reduce the risk of localized serial depletion on the "Snakehead" and other relatively shallow (75 – 150 m) offshore banks on the outer continental shelf were northern rockfish are concentrated.

9.12.2 Assessment Data

The highly variable biomass estimates for northern rockfish suggest that the stratified random design of the surveys does a relatively poor job of assessing stock condition of northern rockfish and that a different survey approach may be needed to reduce the variability in biomass estimates.

9.12.3 Assessment Model Formulation

Future model evaluation include examination of the affect of new maturity schedule that may become available for northern rockfish (Pers. Comm. Liz Chilton); Examination of historical catch which could include splitting catch into three or more time series, based upon reliability of data; Changing age of first recruitment to 4 years to match that seen in the fishery; Changing the plus age group to accommodate older age fish in population; Exploring the use of fishery lengths as well as fishery ages for years with fishery age data; and updating the length-at-age transition matrix with new length at age data, Examination of sensitivity of model to separate selectivities for survey and fishery.

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Table 9-1. Historical commercial catch[a] (mt) of fish in the slope rockfish assemblage in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and fishing quotas[b] (mt), 1977-1992. Commercial catch (mt) of northern rockfish in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and total allowable catch (TAC), 1993-present.

		Gulfwide Regulatory area				Management value	
Year	Fishery category	Western	Central	Eastern	Gulfwide Total	ABC	Quota
1977	Foreign	6,282	6,166	10,993	23,441		
	U.S.	0	0	12	12		
	JV	-	-	-	-		
	Total	6,282	6,166	11,005	23,453	50,000	30,000
1978	Foreign	3,643	2,024	2,504	8,171		
	U.S.	0	0	5	5		
	JV	-	-	-	-		
	Total	3,643	2,024	2,509	8,176	50,000	25,000
1979	Foreign	944	2,371	6,434	9,749		
	U.S.	0	99	6	105		
	JV	1	31	35	67		
	Total	945	2,501	6,475	9,921	50,000	25,000
1980	Foreign	841	3,990	7,616	12,447		
	U.S.	0	2	2	4		
	JV	0	20	0	20		
	Total	841	4,012	7,618	12,471	50,000	25,000
1981	Foreign	1,233	4,268	6,675	12,176		
	U.S.	0	7	0	7		
	JV	1	0	0	1		
	Total	1,234	4,275	6,675	12,184	50,000	25,000
1982	Foreign	1,746	6,223	17	7,986		
	U.S.	0	2	0	2		
	JV	0	3	0	3		
	Total	1,746	6,228	17	7,991	50,000	11,475
1983	Foreign	671	4,726	18	5,415		
	U.S.	7	8	0	15		
	JV	1,934	41	0	1,975		
	Total	2,612	4,775	18	7,405	50,000	11,475
1984	Foreign	214	2,385	0	2,599		
	U.S.	116	0	3	119		
	JV	1,441	293	0	1,734		
	Total	1,771	2,678	3	4,452	50,000	11,475
1985	Foreign	6	2	0	8		
	U.S.	631	13	181	825		
	JV	211	43	0	254		
	Total	848	58	181	1,087	11,474	6,083
1986	Foreign	Tr	Tr	0	Tr		
	U.S.	642	394	1,908	2,944		
	JV	35	2	0	37		
	Total	677	396	1,908	2,981	10,500	3,702
1987	Foreign	0	0	0	0		
	U.S.	1,347	1,434	2,088	4,869		
	JV	108	4	0	112		
	Total	1,455	1,438	2,088	4,981	10,500	5,000

Table 8-1.--(Continued)

Year	Management subgroup	Gulfwide Regulatory area Western	Central	Eastern	Gulfwide Total	Management value ABC	Quota
1988	Foreign	0	0	0	0		
	U.S.	2,586	6,467	4,718	13,771		
	JV	4	5	0	8		
	Total	2,590	6,471	4,718	13,779	16,800	16,800
1989	U.S.	4,339	8,315	6,348	19,002	20,000	20,000
1990	U.S.	5,203	9,973	5,938	21,114	17,700	17,700
1991	POP	1,589	2,956	2,087	6,631	5,800	5,800
	SR/RE	123	408	171	702	2,000	2,000
	Other slope	634	4,011	162	4,806	10,100	10,100
1992	POP	1,266	2,658	2,234	6,159	5,730	5,200
	SR/RE	115	1,367	683	2,165	1,960	1,960
	Other slope	1,068	7,495	875	9,438	14,060	14,060
1993	Northern	902	3,778	145	4,825	5,760	5,760
1994	Northern	1,394	4,519	55	5,968	5,760	5,760
1995	Northern	113	5,476	45	5,634	5,270	5,270
1996	Northern	173	3,146	24	3,343	5,270	5,270
1997	Northern	62	2,870	15	2,947	5,000	5,000
1998	Northern	77	2,967	11	3,055	5,000	5,000
1999	Northern	574	4,825	c	5,399	4,990	4,990
2000	Northern	747	2,578	c	3,325	5,120	5,120
2001	Northern	539	2,588	c	3,127	4,880	4,880
2002	Northern	338	2,999	c	3,337	4,770	4,770
2003	Northern	533	4,810	c	5,343	5,530	5,530
2004	Northern	1,030	3,753	c	4,783	4,870	4,870
2005	Northern	567	4,209	c	4,776	5,091	5,091

Note: There were no foreign or joint venture catches after 1988. Catches prior to 1989 are landed catches only. Catches in 1989 and 1990 also include fish reported in weekly production reports as discarded by processors. Catches in 1991-present also include discarded fish, as determined through a "blend" of weekly production reports and information from the domestic observer program. Definitions of terms: JV = Joint venture; Tr = Trace catches; Other slope = other slope rockfish management subgroup (in 1991-92 consisted of all species in the slope rockfish assemblage except for Pacific ocean perch and shortraker and rougheye rockfish.

[a]Catch defined as follows: 1977, all *Sebastes* rockfish for Japanese catch, and Pacific ocean perch for catches of other nations; 1978, Pacific ocean perch only; 1979-87, the 5 species comprising the Pacific ocean perch complex; 1988-90, the 18 species comprising the slope rockfish assemblage; 1991-93, the 20 species comprising the slope rockfish assemblage; 1994-2002 the 21 species comprising the slope rockfish assemblage.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2001 total allowable catch.

[c]For the years after 1998, exact catches in the Eastern area are not available because northern rockfish in this area were transferred to the "other slope rockfish" management category.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201; 1989-2002, National Marine Fisheries Service, Alaska Region, P.O. Box 21668, Juneau, AK 99802. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987-2000, Heifetz et al. (2000); 2001-present, North Pacific Fishery Management Council web cite 605 W. 4th Ave., Suite 306, Anchorage, Alaska 99501-2252.

Table 9-2.–Estimated commercial catch (mt) of northern rockfish in the Gulf of Alaska, 1977-present[1,3].

Year	Foreign	Joint venture	Domestic	Total
1977	622	0	0	622
1978	553	0	0	553
1979	666	3	0	669
1980	809	Tr[2]	0	809
1981	1,469	0	0	1,469
1982	3,914	0	0	3,914
1983	2,705	911	0	3,616
1984	489	492	10	991
1985	Tr[2]	108	66	174
1986	Tr[2]	11	237	248
1987	0	51	391	442
1988	0	Tr[2]	1,107	1,107
1989	0	0	1,527	1,527
1990	0	0	1,697	1,697
1991	0	0	4,528	4,528
1992	0	0	7,770	7,770
1993	0	0	4,825	4,825
1994	0	0	5,968	5,968
1995	0	0	5,634	5,634
1996	0	0	3,343	3,343
1997	0	0	2,947	2,947
1998	0	0	3,055	3,055
1999	0	0	5,399	5,399
2000	0	0	3,325	3,325
2001	0	0	3,127	3,127
2002	0	0	3,337	3,337
2003	0	0	5,343	5,343
2004	0	0	4,783	4,783
2005	0	0	4,776	4,776

[1]1977-1992, Clausen and Heifetz (2004)

[2]Tr. = trace

[3] 1984-1989, Domestic catches of northern rockfish for years i = {1984, 1985, …, 1989} were estimated for this report by the ratio of domestic northern rockfish catch to domestic slope rockfish catch reported by the 1990 NMFS observer program (see section 9.2.1).

Table 9-3. Catch (mt) of northern rockfish taken during research cruises in the Gulf of Alaska, 1977-2005. (Tr.=trace)

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Catch	Tr.	0.5	1	0.5	8.4	6.4	1.7	11.3	10.8	0.7	40.6	0	0.2	19.2	0
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	
Catch	0	20.8	0	0	12.5	0	2.5	13.2	0	23.4	0	5.6	0	23.2	

Table 9-4. Fishery length compositions for northern rockfish in the Gulf of Alaska.

Length						Year								
class (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
15-24	8	4	0	2	1	42	1	8	18	7	91	8	9	2
25	8	9	1	4	0	47	2	34	2	5	11	1	1	6
26	4	21	3	10	1	74	0	72	6	13	20	10	4	8
27	18	33	4	11	5	97	3	106	5	15	21	16	9	14
28	36	64	17	23	14	88	5	109	9	7	44	24	19	18
29	73	110	38	57	29	110	9	109	14	7	43	57	29	55
30	80	288	78	112	57	134	30	90	24	15	62	79	76	81
31	96	529	173	248	135	164	26	57	23	20	81	88	115	159
32	151	967	385	484	246	222	66	62	60	37	132	110	198	245
33	207	1,733	670	830	568	453	162	108	109	80	148	129	204	379
34	333	2,550	1,247	1,132	946	864	351	206	211	122	189	143	168	378
35	547	2,741	1,912	1,631	1,421	1,364	706	426	475	173	218	174	158	400
36	800	2,008	2,162	1,754	1,623	1,652	1,026	618	891	361	302	226	184	340
37	738	1,222	2,128	1,359	1,391	1,714	1,041	681	1,160	534	363	304	238	339
38	550	610	1,824	1,073	811	1,371	785	616	1,069	685	467	312	283	398
39	360	288	1,286	729	431	863	544	371	771	567	442	280	281	395
40	168	131	810	514	203	400	346	207	445	449	311	223	204	375
41	79	87	443	359	96	211	191	95	207	271	192	133	144	287
42	37	27	165	189	55	162	95	43	82	134	97	102	96	219
43	18	47	59	49	38	117	48	19	46	77	46	66	56	154
44	8	32	55	9	28	97	22	9	19	31	31	38	29	61
45-52	8	86	64	3	39	222	68	2	6	57	29	64	29	56
Total (n)	4,327	13,587	13,524	10,582	8,138	10,468	5,527	4,048	5,652	3,667	3,340	2,587	2,534	4,369
(# hauls)	41	135	112	93	90	114	89	59	84	176	255	244	218	285
Mean length	36.0	34.7	36.6	36.0	35.9	36.3	37.0	35.7	37.3	38.0	36.4	36.9	36.4	36.8

Table 9-5. Fishery age compositions for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

Age Class	1988	1999	Year 2000	2001	2002	2003	2004
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	0.25	-	-
5	-	0.65	1.46	-	-	0.32	0.11
6	0.38	0.32	2.12	0.85	0.74	0.00	1.27
7	0.76	0.65	1.46	4.27	4.07	1.26	1.17
8	3.23	0.00	1.46	2.56	11.59	1.89	3.29
9	2.47	4.22	1.46	2.39	6.91	1.89	10.08
10	3.42	1.30	3.98	3.41	4.32	6.31	14.54
11	5.88	2.92	3.45	4.95	3.70	0.63	4.78
12	7.21	3.90	5.31	3.75	4.32	3.47	2.97
13	9.11	4.87	5.31	5.29	4.81	4.10	3.50
14	9.49	6.17	5.04	5.12	3.21	6.62	2.87
15	7.02	12.66	8.62	4.10	3.70	4.42	3.18
16	7.40	6.49	9.02	5.80	4.56	4.42	2.97
17	3.23	5.84	5.31	9.73	6.91	4.42	2.55
18	3.61	4.22	5.17	5.80	6.54	10.09	3.29
19	2.28	1.95	2.52	4.27	4.19	9.46	5.20
20	2.47	2.27	2.39	2.90	2.71	3.47	5.73
21	4.17	3.25	1.72	2.73	2.59	4.10	3.18
22	4.93	2.92	4.24	3.07	2.10	4.42	3.08
23	3.42	7.47	2.92	3.75	1.11	1.26	2.76
24	2.85	4.22	4.24	2.90	2.71	2.21	0.96
25	2.47	0.97	2.12	4.10	3.82	2.21	1.06
26	2.47	2.60	2.52	3.75	2.34	3.15	2.44
27	1.14	1.62	1.59	1.54	1.60	2.84	3.29
28	0.95	4.22	1.86	1.71	0.74	3.15	3.08
29	2.66	3.57	2.39	1.02	1.23	0.63	1.27
30	1.90	2.27	3.45	1.54	1.36	0.95	1.70
31	0.57	2.92	1.86	2.39	1.23	1.89	1.06
32	0.95	1.30	1.19	1.88	1.48	2.21	0.85
33	1.14	0.32	1.06	0.85	1.11	0.32	1.59
34	-	0.65	0.27	0.51	0.49	1.58	1.06
35	0.19	0.65	0.53	0.34	0.25	0.63	1.06
36	-	-	0.40	0.34	0.37	0.95	1.06
37	0.19	0.65	0.27	1.02	0.49	-	0.21
38	1.33	0.32	0.27	0.68	0.12	0.32	0.21
39	0.19	0.32	0.53	-	0.37	0.32	0.21
40-88	0.57	1.30	1.99	0.68	1.97	4.10	2.34
Sample Size	527	308	754	586	811	317	942
Hauls	46	160	212	198	219	110	308
Port Samples	10	0	24	16	28	0	31
Mean age	17.69	19.63	18.80	18.61	17.11	20.33	18.07

Table 9-6. Biomass estimates (mt), by statistical area, for northern rockfish in the Gulf of Alaska based on triennial and biennial trawl surveys. Gulfwide CV's are also listed.

	Statistical areas						
Year	Shumagin	Chirikof	Kodiak	Yakutat [a]	South-eastern [a]	Total	CV
1984	27,716	5,165	6,448	5	0	39,334	29%
1987	45,038	13,794	77,084	500	0	136,417	29%
1990	32,898	5,792	68,044	343	0	107,076	42%
1993	13,995	40,446	49,998	41	0	104,480	35%
1996	28,114	40,447	30,212	192	0	98,965	27%
1999	45,457	29,946	166,665	118	0	242,187	61%
2001	93,291	24,490	225,833	117	0	343,731	60%
2003	9,146	49,793	7,336	5	0	66,310	48%
2005	231,138	102,605	25,123	160	0	359,026	37%

[a]Biomass estimates are not available for the Yakutat and Southeastern areas in 2001because these areas were not sampled that year. Substitute values are listed in this table and were obtained by averaging the biomass estimates for each of these areas in the 1993, 1996, and 1999 surveys.

Table 9-7. Survey age compositions for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

Age			Year					
Class	1984	1987	1990	1993	1996	1999	2001	2003
2	0.00	0.00	0.00	0.03	0.28	0.00	0.02	0.00
3	0.00	0.30	0.06	0.28	0.30	0.03	0.62	0.07
4	0.00	1.67	0.19	0.31	0.13	0.16	0.08	0.15
5	1.48	5.18	2.91	0.85	0.21	1.05	0.44	3.46
6	4.10	3.84	5.42	1.07	1.13	0.27	1.25	2.11
7	8.91	2.89	2.65	1.09	0.58	0.94	5.05	1.45
8	18.34	0.29	4.08	6.34	2.07	0.89	0.71	9.64
9	10.83	2.85	5.38	11.98	4.10	4.23	3.72	12.63
10	5.08	10.15	4.47	6.53	5.31	2.77	6.97	5.65
11	4.63	11.24	5.77	10.31	8.52	7.92	8.23	3.60
12	2.59	11.25	3.52	4.44	7.58	6.92	4.68	2.92
13	7.23	3.46	5.36	4.90	7.72	5.42	3.40	2.13
14	6.81	4.32	8.24	4.02	4.02	5.62	4.60	5.13
15	6.35	1.42	9.71	2.44	3.29	7.82	5.53	3.33
16	4.05	3.71	5.08	5.19	3.87	9.16	5.22	4.27
17	1.98	10.43	5.08	3.14	1.65	1.56	6.75	0.00
18	1.90	4.15	0.67	3.97	3.41	7.21	7.77	1.76
19	0.59	8.10	1.12	2.81	5.44	1.88	1.76	2.96
20	0.76	2.76	6.56	0.40	8.78	1.30	0.95	6.10
21	0.32	2.59	6.63	2.32	2.77	3.00	0.89	1.19
22	1.01	0.71	4.58	3.41	3.06	2.19	1.99	2.05
23	3.25	0.66	1.92	4.45	3.02	2.51	2.24	1.06
24	2.16	0.29	0.89	4.46	3.33	3.03	6.27	0.66
25	0.66	0.40	0.97	4.64	2.68	1.96	2.23	1.35
26	0.33	1.76	3.37	0.69	5.22	1.50	2.92	2.53
27	1.06	2.62	0.64	1.68	1.36	3.35	1.66	2.99
28	0.37	1.23	1.17	2.22	1.47	2.48	0.86	5.39
29	0.94	0.31	0.18	0.57	2.75	2.40	0.90	3.45
30	0.00	0.23	0.98	0.00	0.57	1.65	2.22	1.56
31	0.42	0.53	0.96	0.24	0.75	2.39	2.12	0.00
32	1.40	0.00	0.90	0.95	0.42	4.54	0.86	0.00
33-60	2.45	0.66	0.54	4.26	4.20	3.85	7.08	10.42
Sample Size	356	497	442	354	462	293	278	383*
Hauls	6	17	14	20	19	29	47	22*
Mean Age	13.15	14.21	15.39	16.21	17.81	18.56	18.15	

*Average of 1984-2001.

Table 9-8. Selected unweighted likelihood values for Models 1-5.

	Model 1 (Base)		Model 2 (Alt Case 2003)		Model 3 (Alt + M Est)		Model 4 (Alt + F Hist.)		Model 5 (Alt + M est + F Hst.)	
Likelihoods	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
Catch	0.01	50	0.00	50	0.00	50	0.00	50	0.00	50
Survey Biomass	9.18	1	9.32	1	10.35	1	8.14	1	7.94	1
Fishery Ages	34.08	1	30.28	1	30.91	1	31.24	1	31.27	1
Survey Ages	39.23	10	45.50	1	47.15	1	46.76	1	46.67	1
Fishery Sizes	105.28	1	67.58	1	68.32	1	68.05	1	68.11	1
Survey Sizes	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Total Data-Likelihood	187.79		152.68		156.73		154.19		153.98	
Penalties	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
Rec. Dev.	18.01	1	30.46	1	2.54	1	-2.76	1	-2.93	1
Fish, Sel. Regularity	0.08	100	1.19	1	1.08	1	1.01	1	1.00	1
Surv. Sel. Regularity	0.00	100	1.17	1	1.15	1	1.21	1	1.19	1
Fish. Sel. Domeshape	0.00	1	0.00	1	0.00	1	0.00	1	0.00	1
Surv. Sel. Domeshape	0.00	1	0.00	1	0.00	1	0.00	1	0.00	1
Fish. Sel. Average	0.00	10	0.00	10	0.00	10	0.00	10	0.00	10
Surv. Sel. Average	0.00	10	0.00	10	0.00	10	0.00	10	0.00	10
Fish. Mort. Reg.	28.54	1	3.12	0.1	3.49	0.1	2.59	0.1	2.54	0.1
Total Penalties	47.52		35.95		8.27		2.06		1.81	
Priors	Value	LN Prior(μ,σ)	Value	LN Prior(μ,σ)	Value	LN Prior(μ,σ)	Value	LN Prior(μ,σ)	Value	LN Prior(μ,σ)
M		Fixed		Fixed	0.289	(0.06,0.01)		Fixed	0.23	(0.06,0.01)
Q	0.924	(1,0.2)	0.099	(1,0.2)	0.146	(1,0.2)	0.44	(1,0.2)	0.33	(1,0.2)
Sigr	0.002	(0.9,0.2)	0.154	(1.7,0.002)	10.501	(1.7,0.02)	12.95	(1.7,0.02)	13.03	(1.7,0.02)
Steepness	0.028	(0.9,0.2)							0.00	
Total Priors	0.95		0.25		10.94		13.40		13.59	
Total Obj. Funct.	236.26		188.88		175.94		169.65		169.38	

Table 9-9. Maximum likelihood estimates (MLE) of key parameters from Models 1-5 along with standard errors derived from the Hessian matrix (σ) and MCMC (σMCMC), and Bayesian confidence intervals (BCI) derived from MCMC.

Model 1 (Base)

Parameter	μ	σ	CV Hessian	σ(MCMC)	CV(MCMC)	BCI-Lower	BCI-Upper
q	0.54	0.124	23%	0.116	21%	0.25	0.69
σ_r	0.88	0.111	13%	0.202	23%	1.06	1.85
Steepness	1.00	0.000	0%	0.021	2%	0.92	0.99
Bzero	49,983	10,357	21%	14,574	29%	29,258	85,374
F40%	0.06	0.010	18%	0.011	20%	0.04	0.09

Model 2 (Alt Case 2003)

Parameter	μ	σ	CV Hessian	σ(MCMC)	CV(MCMC)	BCI-Lower	BCI-Upper
q	0.82	0.234	29%	0.211	26%	0.41	1.22
σ_r	1.69	0.024	1%	0.024	1%	1.65	1.74
F40%	0.07	0.012	19%	0.014	21%	0.05	0.10

Model 3 (Alt + M Estimated)

Parameter	μ	σ	CV Hessian	σ(MCMC)	CV(MCMC)	BCI-Lower	BCI-Upper
M	0.065	0.0055	8%	0.0056	9%	0.052	0.074
q	0.79	0.212	27%	0.224	29%	0.39	1.25
σ_r	0.89	0.111	12%	0.176	20%	1.14	1.83
F40%	0.07	0.014	20%	0.015	22%	0.05	0.11

Model 4(Alt + F Hist.)

Parameter	μ	σ	CV Hessian	σ(MCMC)	CV(MCMC)	BCI-Lower	BCI-Upper
q	0.66	0.192	29%	0.203	31%	0.35	1.12
σ_r	0.83	0.102	12%	0.168	20%	1.08	1.73
F40%	0.07	0.012	19%	0.014	21%	0.05	0.10
Historic F	0.074	0.036	48%	0.060	80%	0.002	0.219

Model 5 (Alt + M Estimated + F Hist.)

Parameter	μ	σ	CV Hessian	σ(MCMC)	CV(MCMC)	BCI-Lower	BCI-Upper
M	0.056	0.0052	9%	0.0056	10%	0.052	0.074
q	0.70	0.209	30%	0.224	32%	0.39	1.25
σ_r	0.83	0.102	12%	0.176	21%	1.14	1.83
F40%	0.06	0.013	20%	0.015	24%	0.05	0.11
Historic F	0.080	0.0369	46%	0.0613	77%	0.0003	0.2215

Table 9-10. Maximum likelihood estimates (MLE) of key parameters and results from Models 1-5.

Model Results	Model 1 (Base)	Model 2 (Alt Case 2003)	Model 3 (Alt + M Est)	Model 4 (Alt + F Hist.)	Model 5* (Alt + M Est + F Hist.)
Expl. Biomass 2006 (mt)	80,909	71,835	61,408	127,180	122,591
B40% (mt)	20,696	18,134	18,038	27,688	29,559
Biomass 2006 (mt)	26,280	20,439	17,569	37,173	36,199
F50%	0.041	0.046	0.046	0.046	0.046
Yield in 2006 at F50%	2,815	2,506	2,135	4,474	4,333
F40%	0.058	0.066	0.066	0.066	0.062
FABC 2006 (F40%)	0.058	0.066	0.066	0.066	0.062
ABC 2006 (mt)	3,964	3,582	3,051	6,393	5,857
F OFL 2006 (F35%)	0.070	0.080	0.080	0.080	0.075
OFL 2006 (mt)	4,715	4,300	3,662	7,674	7,033

* Model 5 recommended for ABC determinations

Table 9-11. Estimated time series of female spawning biomass, total exploitable biomass, 6+ biomass (age 6 and greater), catch/(6+ biomass), and the number of age two recruits for northern rockfish in the Gulf of Alaska based an age structured model.

Year	Spawning Biomass (mt)		Exploitable Biomass (mt)		6+ Total Biomass (mt)		Catch / (6+ Total Biomass)		Age Two Recruits (1000's)	
	Current	Previous*	Current	Previous*	Current	Previous*	Current	Previous*	Current	Previous*
1977	15,628	25,489	44,022	71,536	70,949	92,351	0.009	0.007	21,411	29,523
1978	17,362	26,146	49,670	78,381	74,990	93,702	0.007	0.006	75,597	67,574
1979	19,313	27,230	56,252	85,551	79,406	98,119	0.008	0.007	19,809	17,352
1980	21,418	28,671	64,005	91,623	83,589	99,981	0.010	0.008	13,782	15,735
1981	23,633	30,387	71,816	96,217	88,400	105,176	0.017	0.014	12,052	7,213
1982	25,726	32,100	74,419	98,149	104,229	118,026	0.038	0.033	14,953	15,772
1983	26,975	33,074	74,770	99,101	107,312	119,166	0.034	0.03	14,885	19,735
1984	28,262	34,101	76,812	101,435	108,980	119,764	0.009	0.008	18,192	26,906
1985	30,475	35,954	81,150	106,935	112,261	120,610	0.002	0.001	17,719	22,884
1986	33,025	38,071	89,841	113,405	116,252	123,271	0.002	0.002	38,001	59,506
1987	35,580	40,130	103,754	117,836	119,556	126,240	0.004	0.004	17,053	16,043
1988	38,055	42,077	107,140	119,733	122,847	130,287	0.009	0.008	12,207	16,754
1989	40,190	43,700	108,351	121,045	125,029	132,845	0.012	0.011	14,472	19,441
1990	41,964	45,036	108,841	122,680	130,923	142,732	0.013	0.012	12,020	16,329
1991	43,405	46,155	109,605	125,239	132,601	144,331	0.034	0.031	11,113	4,472
1992	43,441	46,093	107,904	125,794	130,104	142,781	0.060	0.054	14,836	24,442
1993	41,911	44,817	103,281	123,696	124,513	138,309	0.039	0.035	11,404	12,511
1994	41,342	44,475	102,399	123,813	121,149	135,709	0.049	0.044	9,523	8,185
1995	40,216	43,732	102,323	121,374	116,226	129,218	0.048	0.044	9,698	2,312
1996	39,187	43,053	98,653	117,367	112,285	126,715	0.030	0.026	78,548	31,265
1997	38,957	43,055	96,491	115,224	109,901	124,098	0.027	0.024	27,173	4,959
1998	38,796	43,046	94,933	113,004	107,384	120,742	0.028	0.025	18,460	17,990
1999	38,516	42,776	92,798	110,274	104,642	115,714	0.052	0.047	19,265	17,990
2000	37,184	41,335	88,659	105,259	114,407	114,104	0.029	0.029	36,121	17,990
2001	36,755	40,501	87,768	102,174	117,591	109,672	0.027	0.029	16,801	17,990
2002	36,547	39,583	87,666	98,687	119,331	105,133	0.028	0.032	19,917	17,990
2003	36,479	38,445	86,929	95,098	120,844	100,110	0.044	0.051	19,917	17,990
2004	35,884	36,482	88,451	90,058	123,799	95,149	0.039		19,917	17,990
2005	35,866		98,758		123,532		0.039		19,917	
2006**	36,199		99,554		122,591		0.050		19,917	
2007**	35,866		97,161		119,944		0.050		19,917	
2008**	35,703		95,818		117,246		0.051			

*Previous estimates from 2003 full assessment for 2004. ** Projections based on average recruitment from 1979-2001 (1977-1999 yearclasses) and projected catch at F40% in 2006 and 2007 from model 5.

Table 9-12. Estimated numbers (thousands) in 2006, fishery selectivity (assumed equal to survey selectivity) of northern rockfish in the Gulf of Alaska based on Model 5. Also shown are schedules of age specific weight and female maturity.

Age	Numbers in endyr+1 (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	19,917	1	63	0.05	1
3	17,240	2	103	0.1	2
4	16,285	3	153	0.5	4
5	15,211	4	210	1	8
6	14,088	6	273	4	14
7	12,600	9	336	10	19
8	25,476	13	399	19	40
9	12,712	18	458	25	100
10	11,360	25	512	47	100
11	15,424	33	561	100	100
12	40,063	43	603	100	100
13	4,428	52	641	100	100
14	3,894	62	672	100	100
15	4,233	71	699	100	100
16	5,009	78	722	100	100
17	3,395	84	740	100	100
18	3,299	89	756	100	100
19	3,615	92	769	100	100
20	2,772	95	780	100	100
21	3,499	96	788	100	100
22	6,961	97	795	100	100
23+	36,975	98	801	100	100

Table 9-13. Northern rockfish spawning biomass, fishing mortality, and yield for seven harvest scenarios based on Model 5. B40% = 29,559 mt, B35% = 25,864 mt, F40% = 0.062, F35% = 0.0754.

Year	Maximum permissible F	Author's F[2]	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished?
Spawning biomass (mt)							
2005	35,866	35,866	35,866	35,866	35,866	35,866	35,866
2006	36,199	36,199	36,199	36,199	36,199	36,199	36,199
2007	36,266	36,336	37,332	37,304	38,431	35,833	36,266
2008	36,361	36,430	38,491	38,435	40,755	35,512	36,361
2009	36,405	36,472	39,591	39,505	43,080	35,161	35,969
2010	36,315	36,382	40,544	40,429	45,311	34,698	35,459
2011	36,094	36,162	41,318	41,173	47,376	34,138	34,846
2012	35,753	35,823	41,905	41,733	49,243	33,494	34,146
2013	35,318	35,393	42,322	42,123	50,905	32,796	33,391
2014	34,824	34,908	42,595	42,371	52,374	32,079	32,616
2015	34,311	34,406	42,765	42,519	53,683	31,378	31,860
2016	33,808	33,917	42,868	42,601	54,863	30,719	31,149
2017	33,334	33,459	42,931	42,645	55,944	30,118	30,498
2018	32,863	33,006	42,916	42,614	56,864	29,561	29,890
Fishing mortality							
2005	0.051	0.051	0.051	0.051	0.051	0.051	0.051
2006	0.062	0.060	0.031	0.032	0.000	0.075	0.062
2007	0.062	0.062	0.031	0.032	0.000	0.075	0.062
2008	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2009	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2010	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2011	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2012	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2013	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2014	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2015	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2016	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2017	0.062	0.062	0.031	0.032	0.000	0.075	0.075
2018	0.062	0.062	0.031	0.032	0.000	0.074	0.074
Yield (mt)							
2005	4,776	4,776	4,776	4,776	4,776	4,776	4,776
2006	5,891	5,891	2,989	3,065	0	7,074	5,891
2007	5,791	5,802	3,023	3,097	0	6,873	5,791
2008	5,752	5,762	3,082	3,156	0	6,752	6,907
2009	5,796	5,805	3,181	3,255	0	6,737	6,879
2010	5,648	5,657	3,177	3,249	0	6,500	6,628
2011	5,516	5,525	3,173	3,243	0	6,291	6,406
2012	5,398	5,408	3,170	3,238	0	6,106	6,208
2013	5,291	5,301	3,167	3,233	0	5,941	6,032
2014	5,198	5,211	3,164	3,229	0	5,799	5,880
2015	5,128	5,148	3,169	3,232	0	5,689	5,760
2016	5,066	5,089	3,173	3,235	0	5,588	5,655
2017	5,009	5,031	3,176	3,237	0	5,470	5,543
2018	4,956	4,985	3,177	3,237	0	5,335	5,411

[2] The 2007 ABC and OFL were projected using an expected catch value of 5.702 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author’s F method was used for this projection (Table 9-13) in response to management requests for a more accurate one-year projection.

Table 9-14. Analysis of ecosystem considerations for northern rockfish.

Indicator	Observation	Interpretation	Evaluation
Ecosystem effects on stock			
Prey availability or abundance trends	important for larval and post-larval survival, but no information known	may help to determine yearclass strength	possible concern if some information available
Predator population trends	Unknown		little concern for adults
Changes in habitat quality	Variable	variable recruitment	possible concern
Fishery effects on ecosystem			
Fishery contribution to bycatch			
Prohibited species	Unknown		
Forage (including herring, Atka mackerel, cod, and pollock)	Unknown		
HAPC biota (seapens/whips, corals, sponges, anemones)	fishery disturbing hard-bottom biota, i.e., corals, sponges	could harm the ecosys- tem by reducing shelter for some species	concern
Marine mammals and birds	probably few taken		little concern
Sensitive non-target species	Unknown		
Fishery concentration in space and time	little overlap be- tween fishery and reproductive activities	fishery does not hinder reproduction	little concern
Fishery effects on amount of large size target fish	no evidence for tar- geting large fish	large fish and small fish are both in population	little concern
Fishery contribution to discards and offal production	discard rates moderate to high for some species of slope rockfish	little unnatural input of food into the ecosystem	some concern
Fishery effects on age-at-maturity and fecundity	fishery is catching some immature fish	could reduce spawn- ing potential and yield	possible concern

Table 9-15. Average bycatch (kg) and bycatch rates during 1997 - 99 of living substrates in the Gulf of Alaska; POT - pot gear; BTR - bottom trawl; HAL - Hook and line (source - Draft Programmatic SEIS).

		Bycatch (kg)				Target catch (mt)	Bycatch rate (kg/mt target)			
Target fishery	Gear	Coral	Anemone	Sea whips	Sponge		Coral	Anemone	Sea whips	Sponge
Arrowtooth flounder	POT	0	0	0	0	4	0.0000	0.0000	0.0000	0.0000
Arrowtooth flounder	BTR	58	99	13	24	2,097	0.0276	0.0474	0.0060	0.0112
Deep water flatfish	BTR	1,626	481	5	733	2,001	0.8124	0.2404	0.0024	0.3663
Rex sole	BTR	321	306	11	317	2,157	0.1488	0.1417	0.0053	0.1468
Shallow water flatfish	POT	0	0	0	0	5	0.0000	0.0000	0.0000	0.0000
Shallow water flatfish	BTR	53	4,741	115	403	2,024	0.0261	2.3420	0.0567	0.1993
Flathead sole	BTR	3	267	1	136	484	0.0071	0.5522	0.0019	0.2806
Pacific cod	HAL	28	4,419	961	33	10,765	0.0026	0.4105	0.0893	0.0030
Pacific cod	POT	0	14	0	1,724	12,863	0.0000	0.0011	0.0000	0.1340
Pacific cod	BTR	34	5,767	895	788	37,926	0.0009	0.1521	0.0236	0.0208
Pollock	BTR	1,153	55	0	23	2,465	0.4676	0.0222	0.0000	0.0092
Pollock	PTR	41	110	0	0	97,171	0.0004	0.0011	0.0000	0.0000
Demersal shelf rockfish	HAL	0	0	0	141	226	0.0000	0.0000	0.0000	0.6241
Northern rockfish	BTR	25	90	0	103	1,938	0.0127	0.0464	0.0000	0.0532
Other slope rockfish	HAL	0	0	0	0	14	0.0000	0.0000	0.0000	0.0000
Other slope rockfish	BTR	0	0	0	0	193	0.0000	0.0000	0.0000	0.0000
Pelagic shelf rockfish	HAL	0	0	0	0	203	0.0000	0.0000	0.0000	0.0000
Pelagic shelf rockfish	BTR	324	176	3	245	1,812	0.1788	0.0969	0.0017	0.1353
Pacific ocean perch	BTR	549	90	5	1,968	6,564	0.0837	0.0136	0.0007	0.2999
Pacific ocean perch	PTR	7	0	0	55	1,320	0.0052	0.0000	0.0000	0.0416
Shortraker/rougheye	HAL	6	0	0	0	19	0.3055	0.0000	0.0000	0.0000
Shortraker/rougheye	BTR	0	18	0	0	21	0.0000	0.8642	0.0000	0.0000
Sablefish	HAL	156	154	68	27	11,143	0.0140	0.0138	0.0061	0.0025
Sablefish	BTR	0	0	0	0	27	0.0000	0.0000	0.0000	0.0000
Shortspine thornyhead	HAL	0	0	0	0	2	0.0000	0.0000	0.0000	0.0000
Shortspine thornyhead	BTR	0	9	0	1	2	0.0000	4.8175	0.0000	0.4069

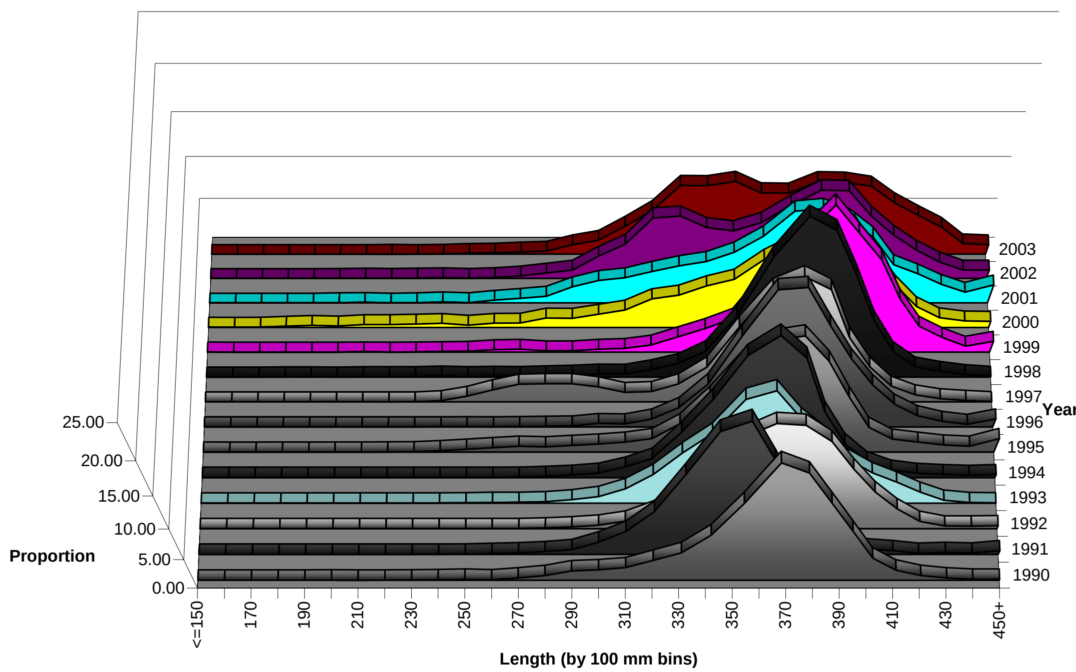

Figure 9-1.– Fishery length compositions for northern rockfish in the Gulf of Alaska.

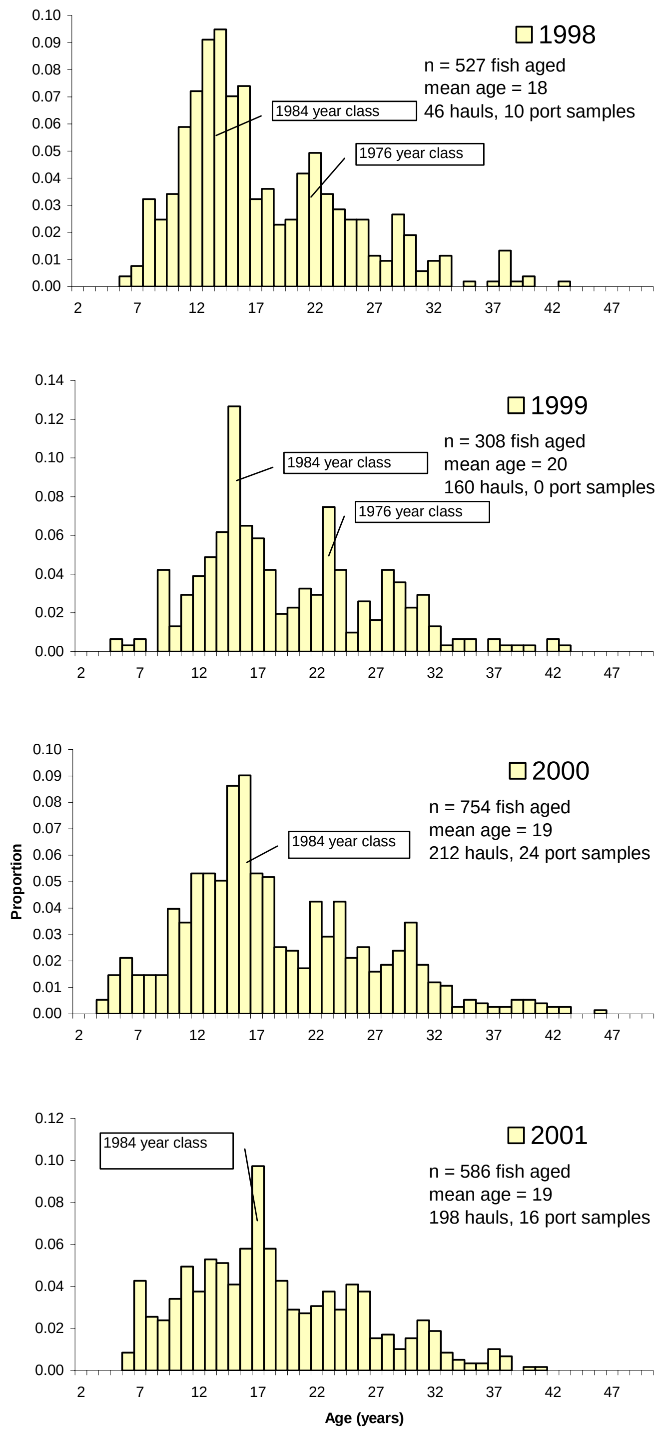

Figure 9-2.–Fishery age compositions for northern rockfish in the Gulf of Alaska.

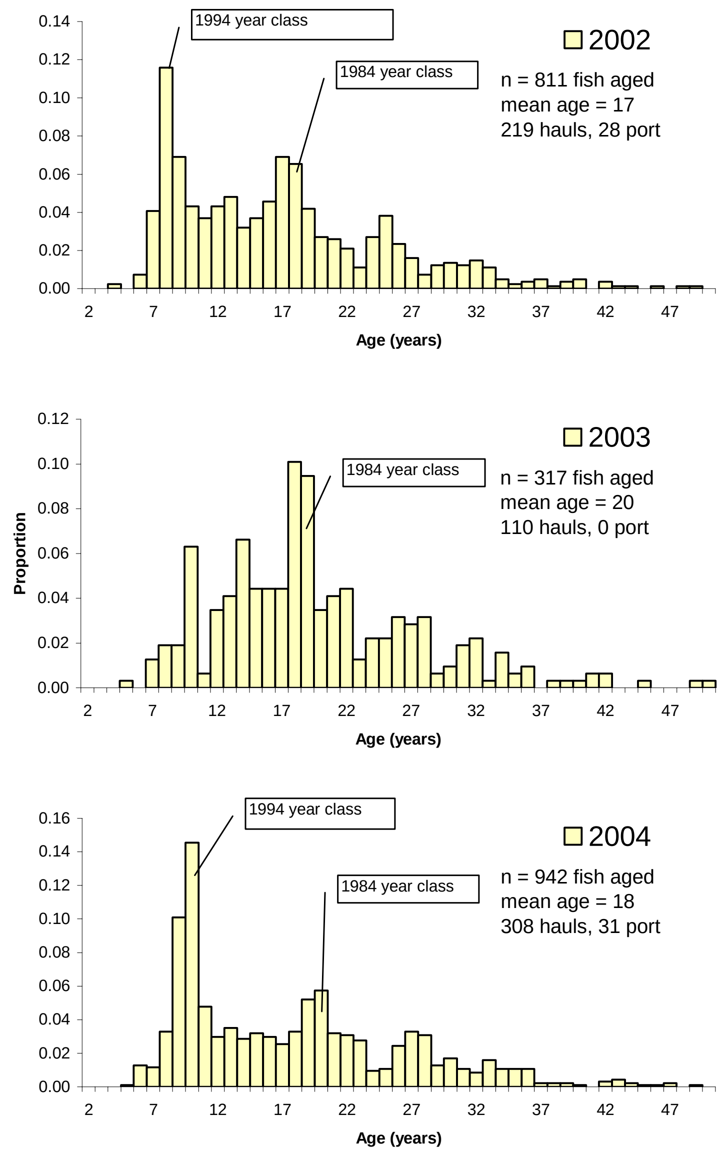

Figure 9-2.–Fishery age compositions continued.

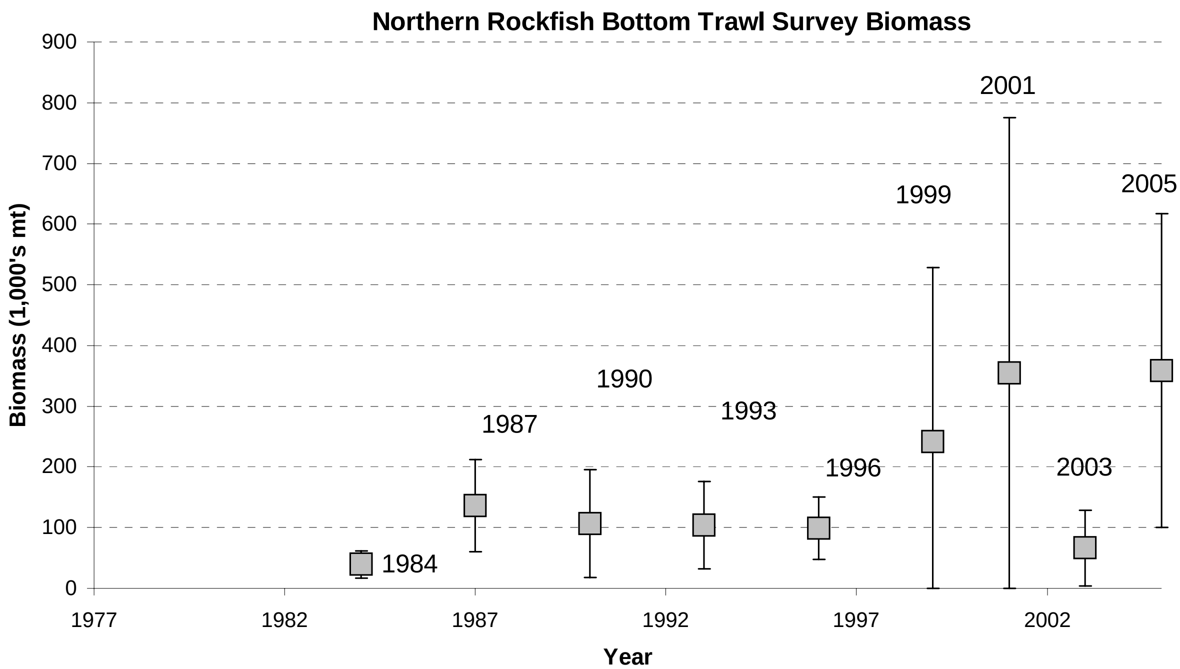

Figure 9-3.--Estimated biomass of northern rockfish in the Gulf of Alaska based on trawl surveys from 1984 to 2005. Vertical bars represent 95% confidence intervals.

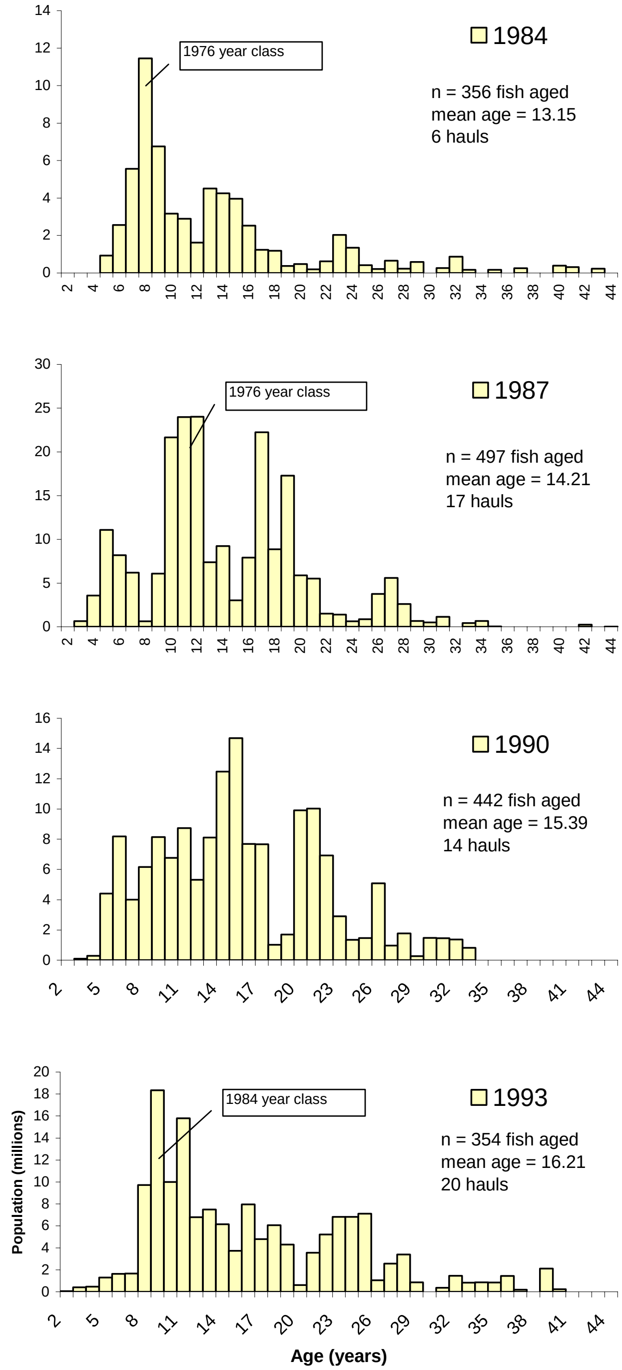

Figure 9-4. Survey age compositions (estimated population in millions) for northern rockfish in the Gulf of Alaska.

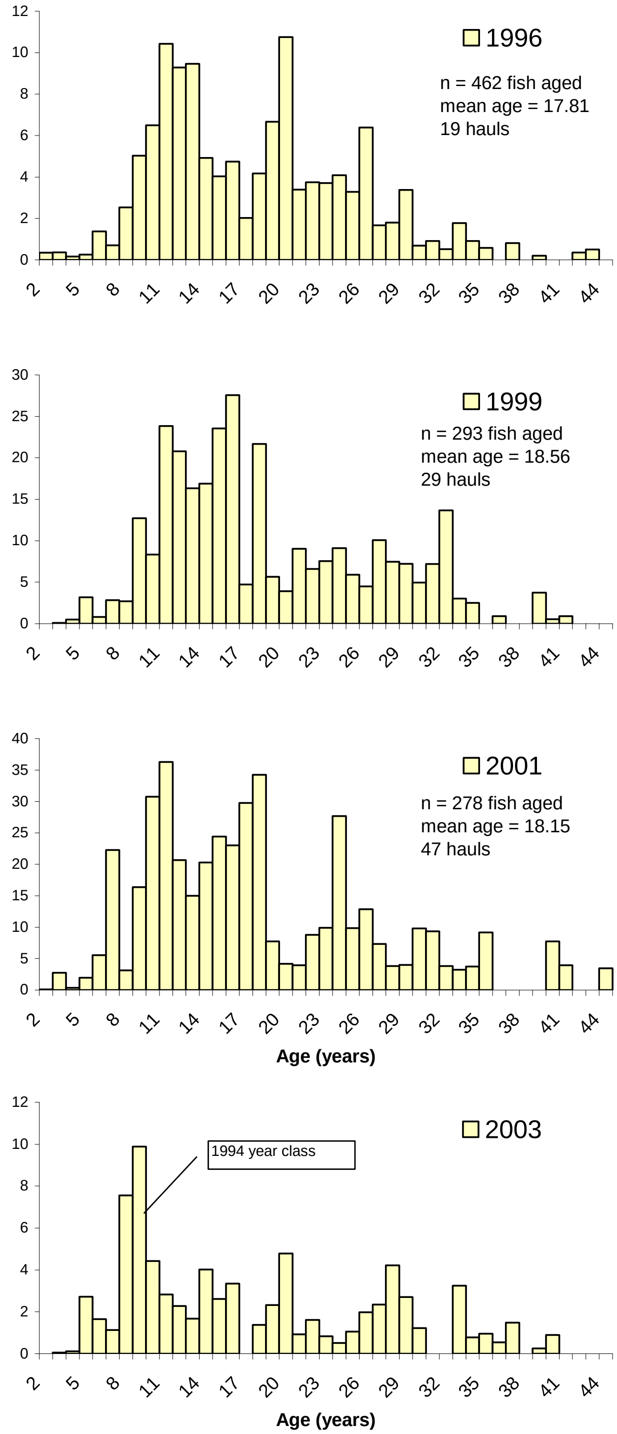

Figure 9-4.–Survey age compositions continued.

Model 1

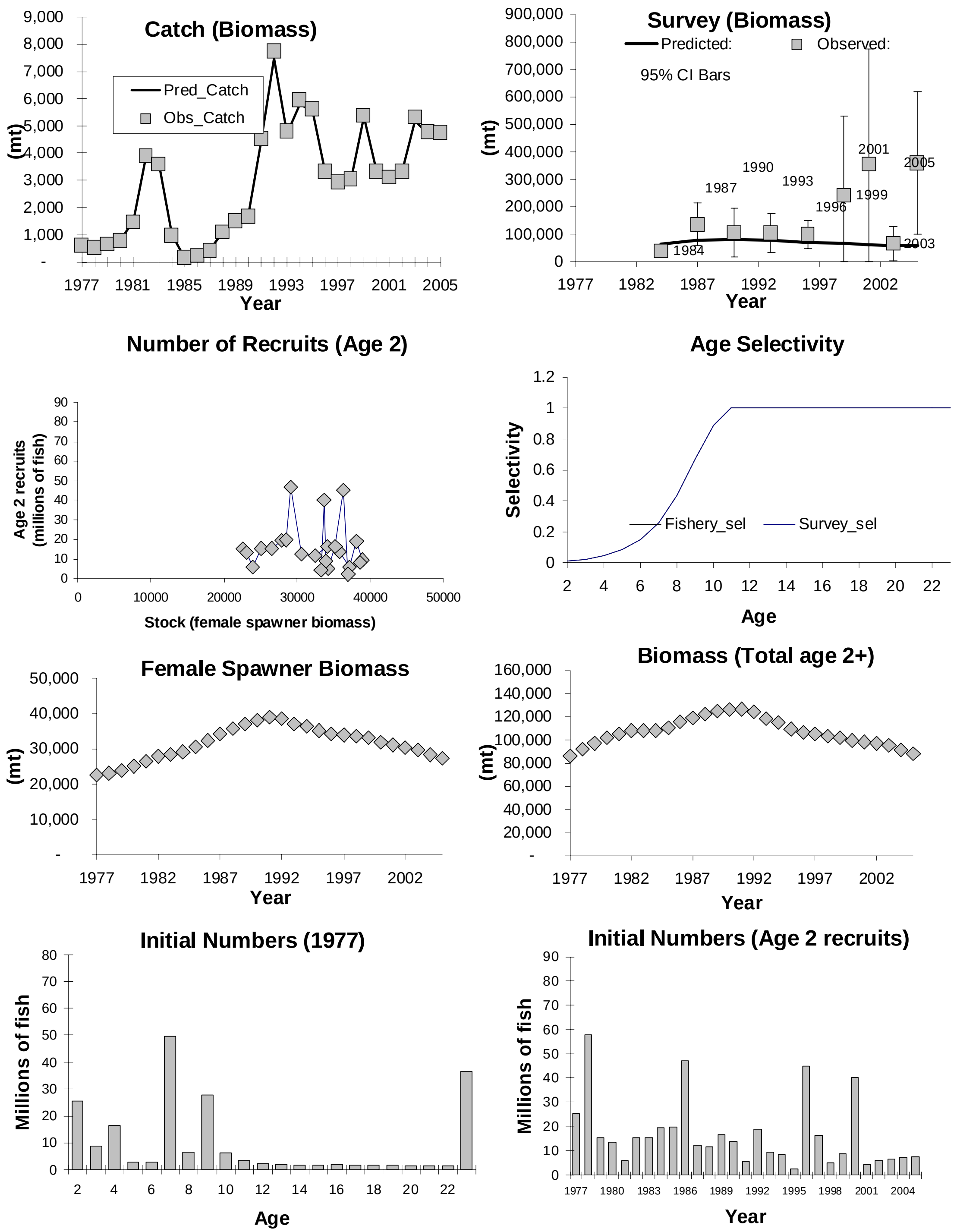

Figure 9-5.–Summary of results for Model 1 (Base).

Model 5

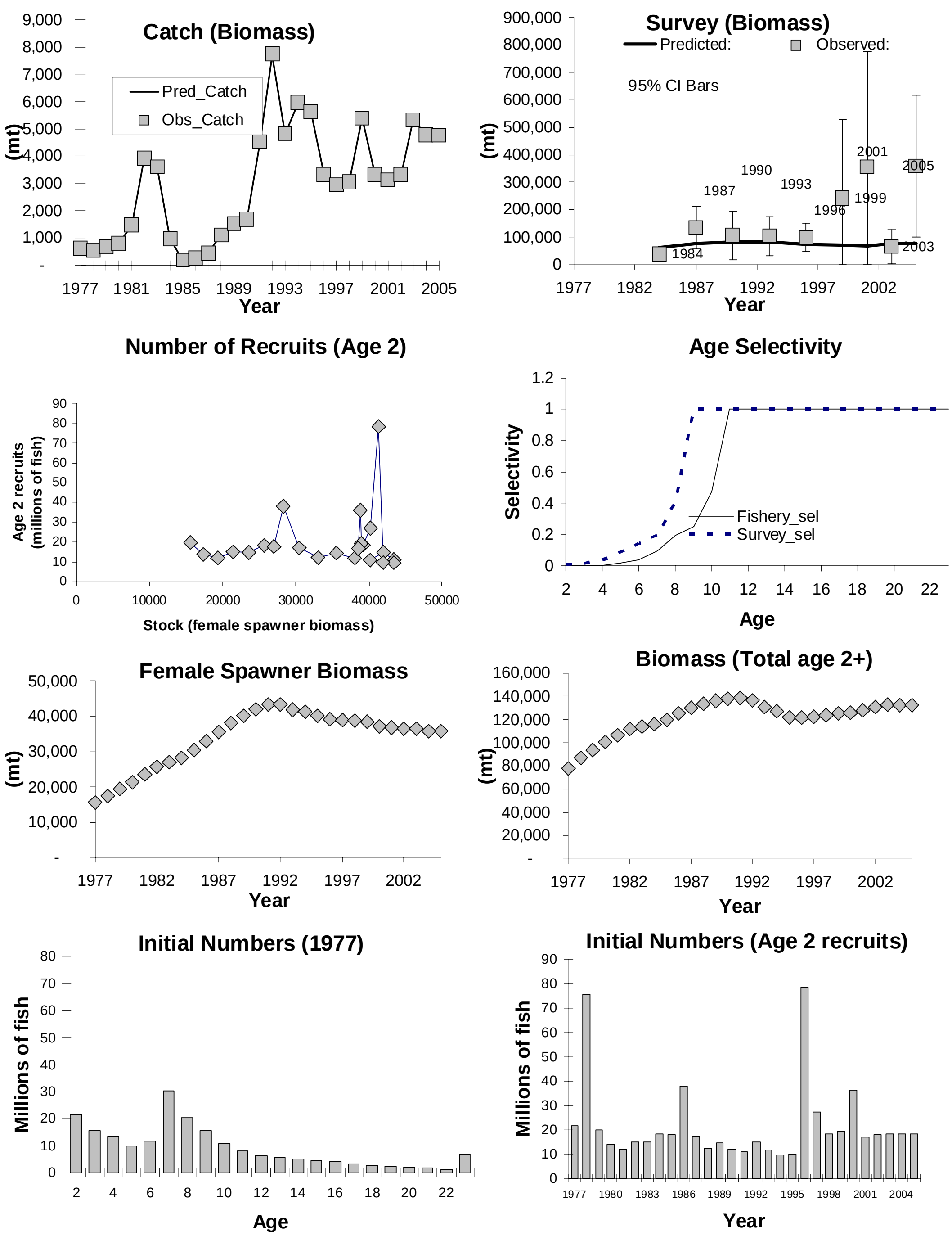

Figure 9-6. Summary of results for Model 5 (Alternative).

Model 1

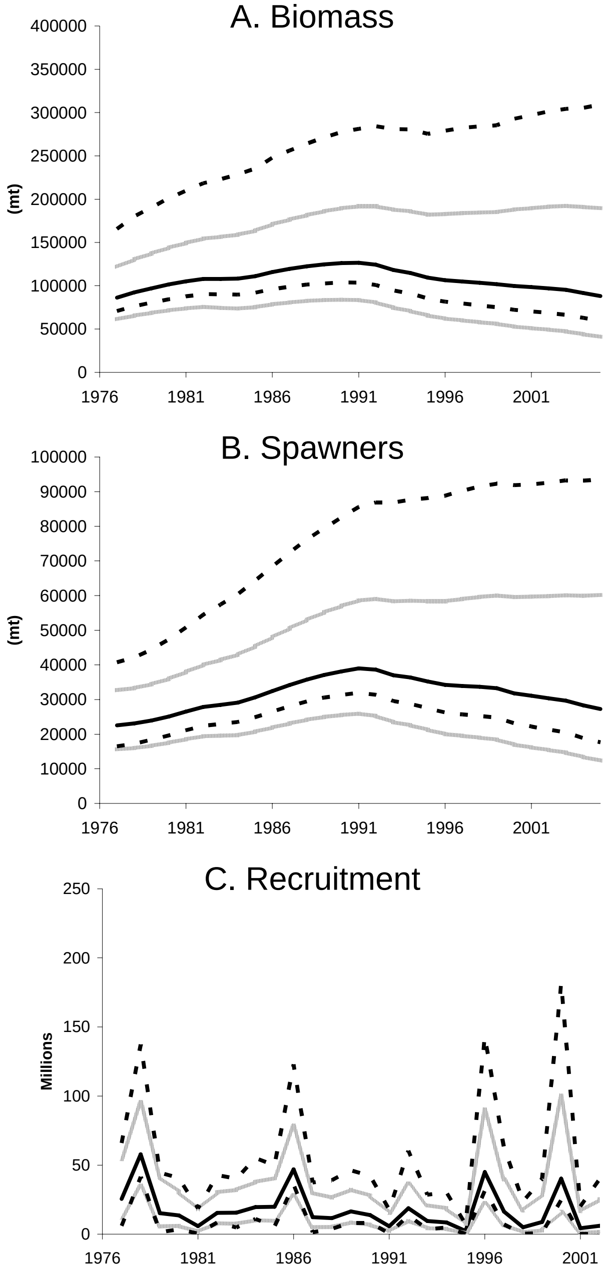

Figure 9-7.–Biomass, spawners, and recruitment (solid line) with 95% confidence intervals from the Hessian Matrix (grey line) and MCMC (stippled line) from Model 1.

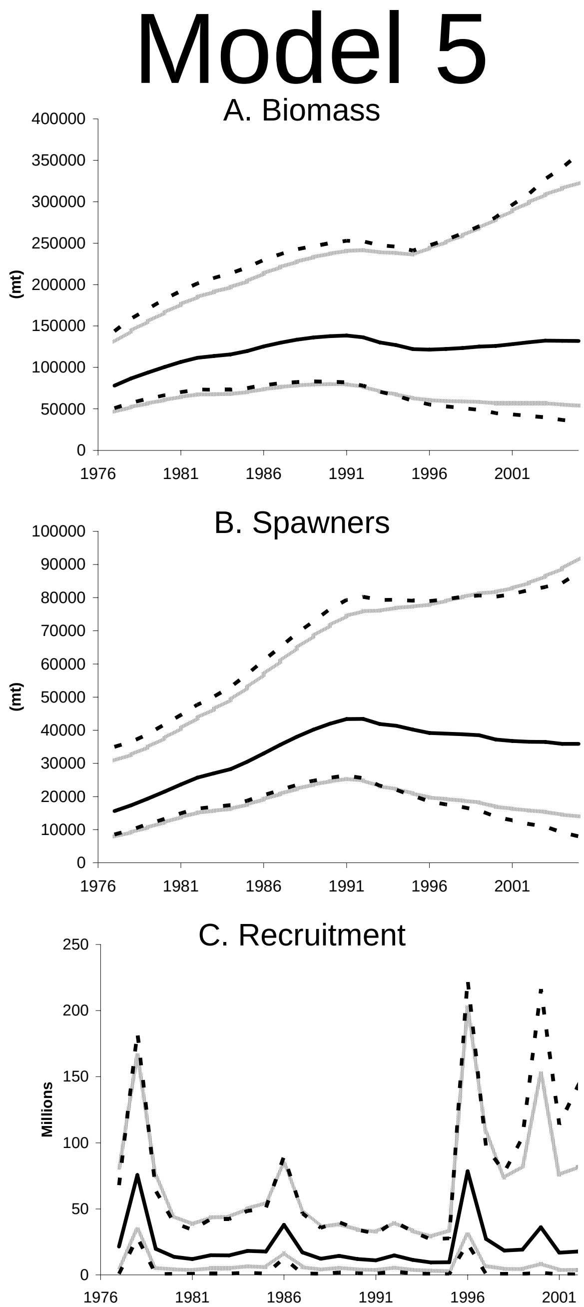

Figure 9-8. Biomass, spawners, and recruitment (solid line) with 95% confidence intervals from the Hessian Matrix (grey line) and MCMC (stippled line) from Model 5.

Models 1-5

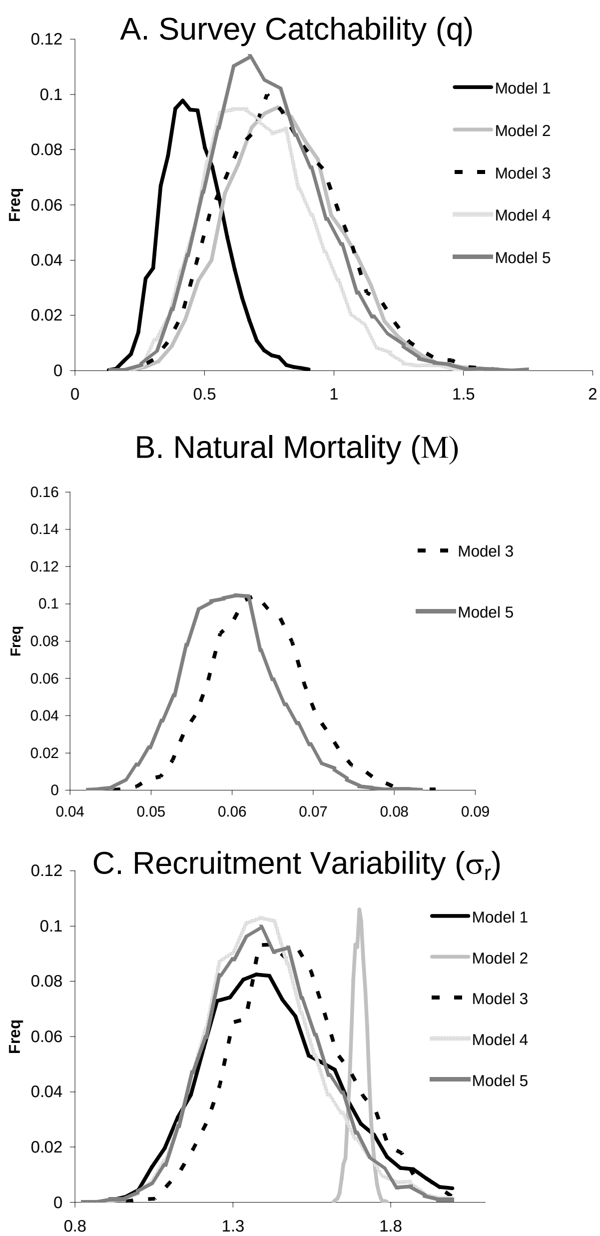

Figure 9-9. MCMC posterior distributions for trawl survey catchability (q), natural mortality (M), and recruitment variability (σ_r) from Models 1-5.

Models 1-5

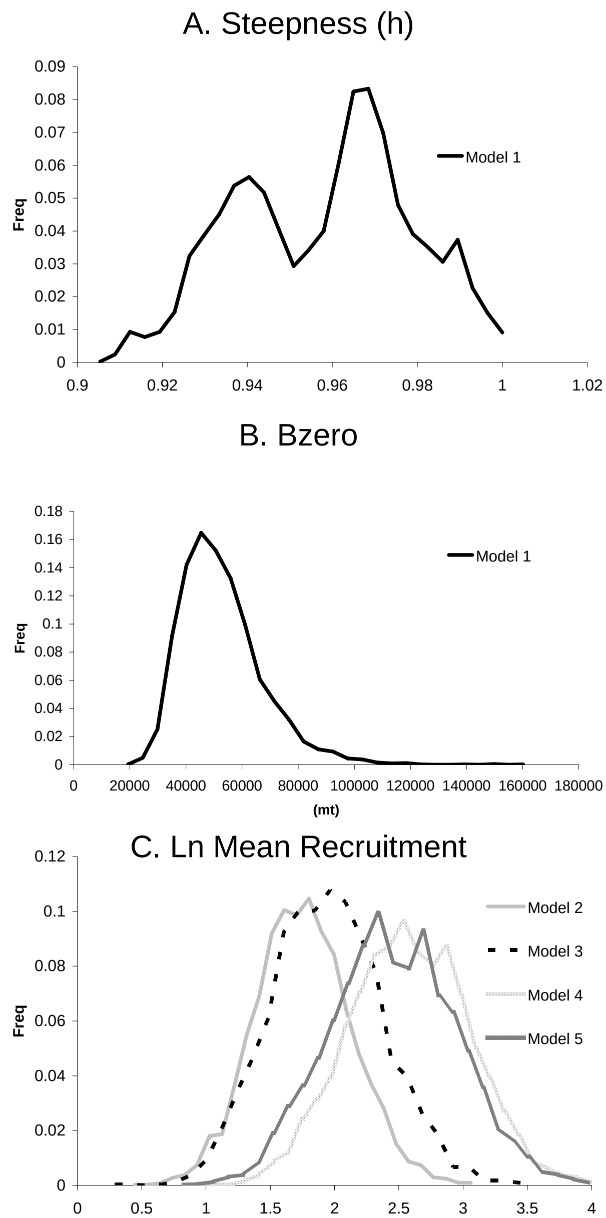

Figure 9-10. MCMC posterior distributions for Beverton Holt S-R parameters Steepness (h) and Bzero from Model 1 and natural log (Ln) of mean recruitment from Models 2-5.

Models 1-5

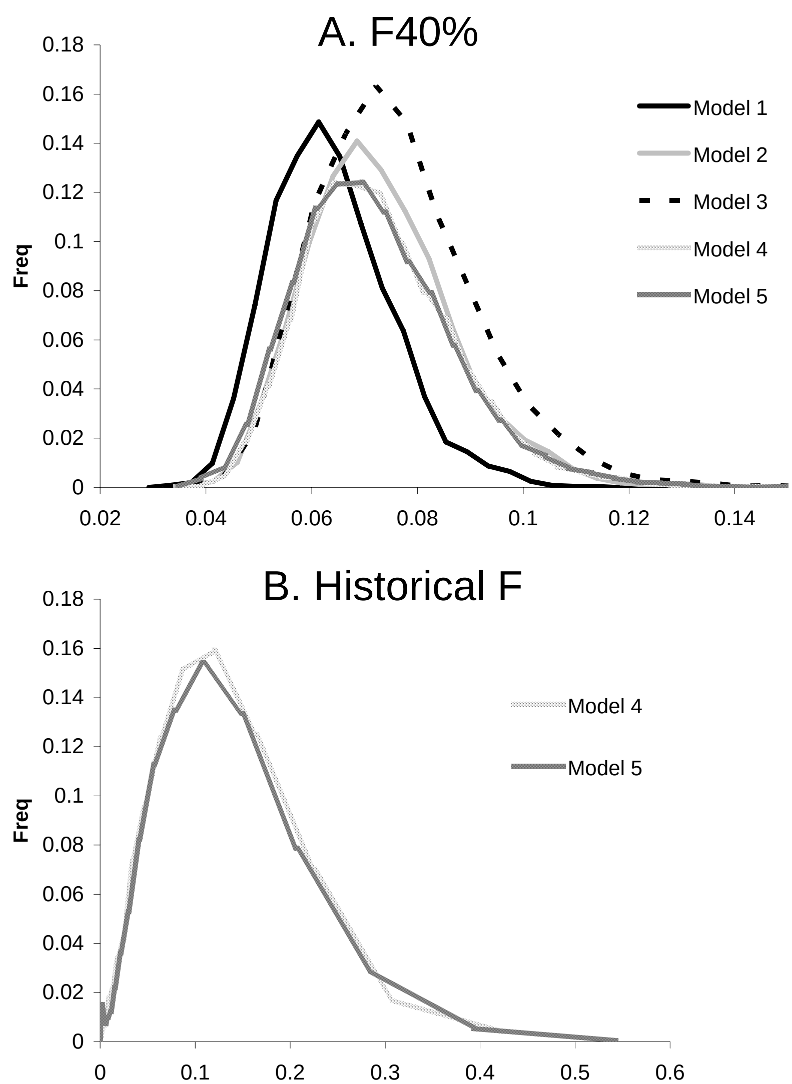

Figure 9-11. MCMC posterior distributions for F40% from Models 1-5 and for historical F from Models 4 and 5.

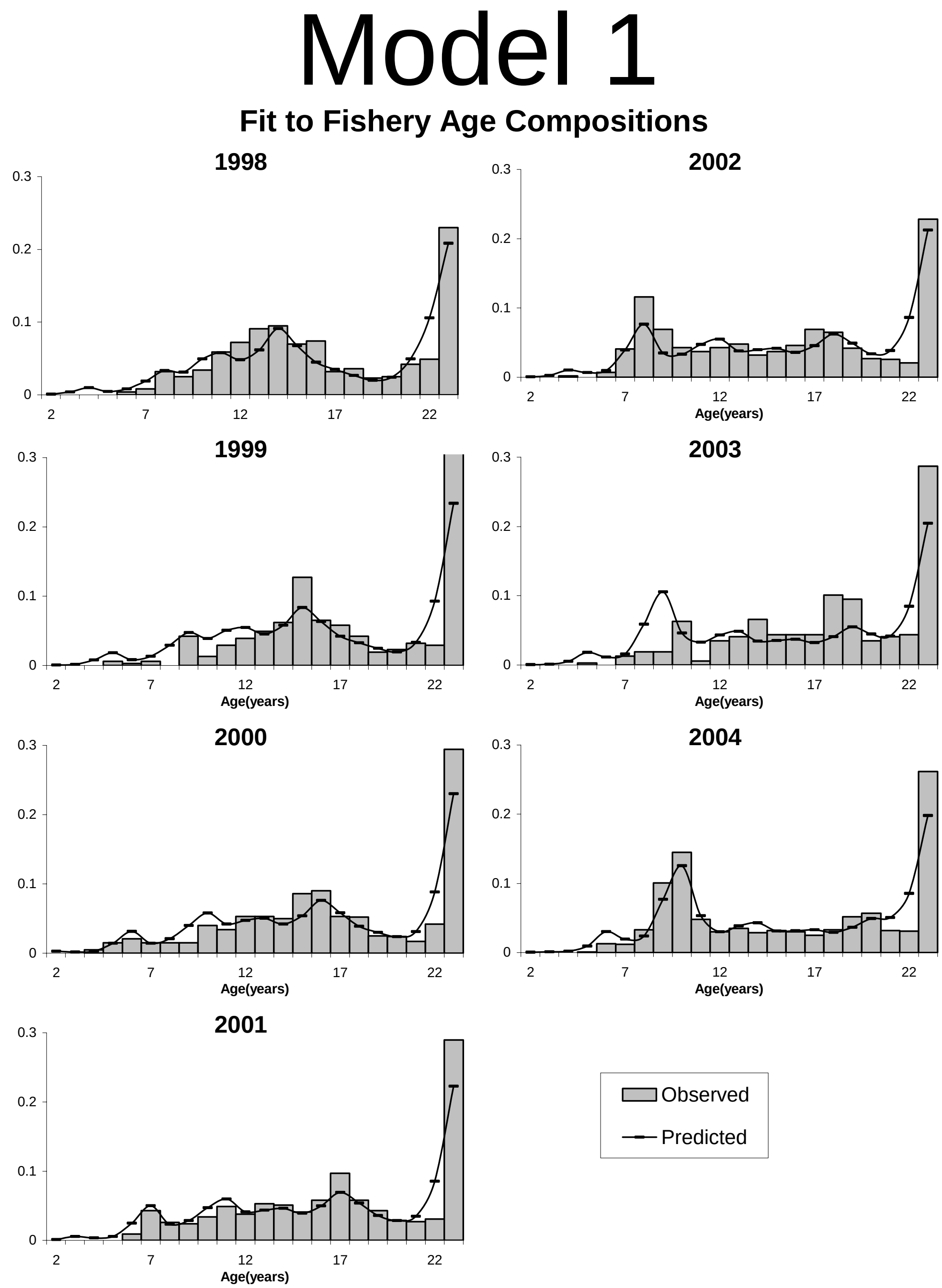

Figure 9-12. –Observed and predicted fishery age compositions from Model 1.

Model 1

Fit to Survey Age Compositions

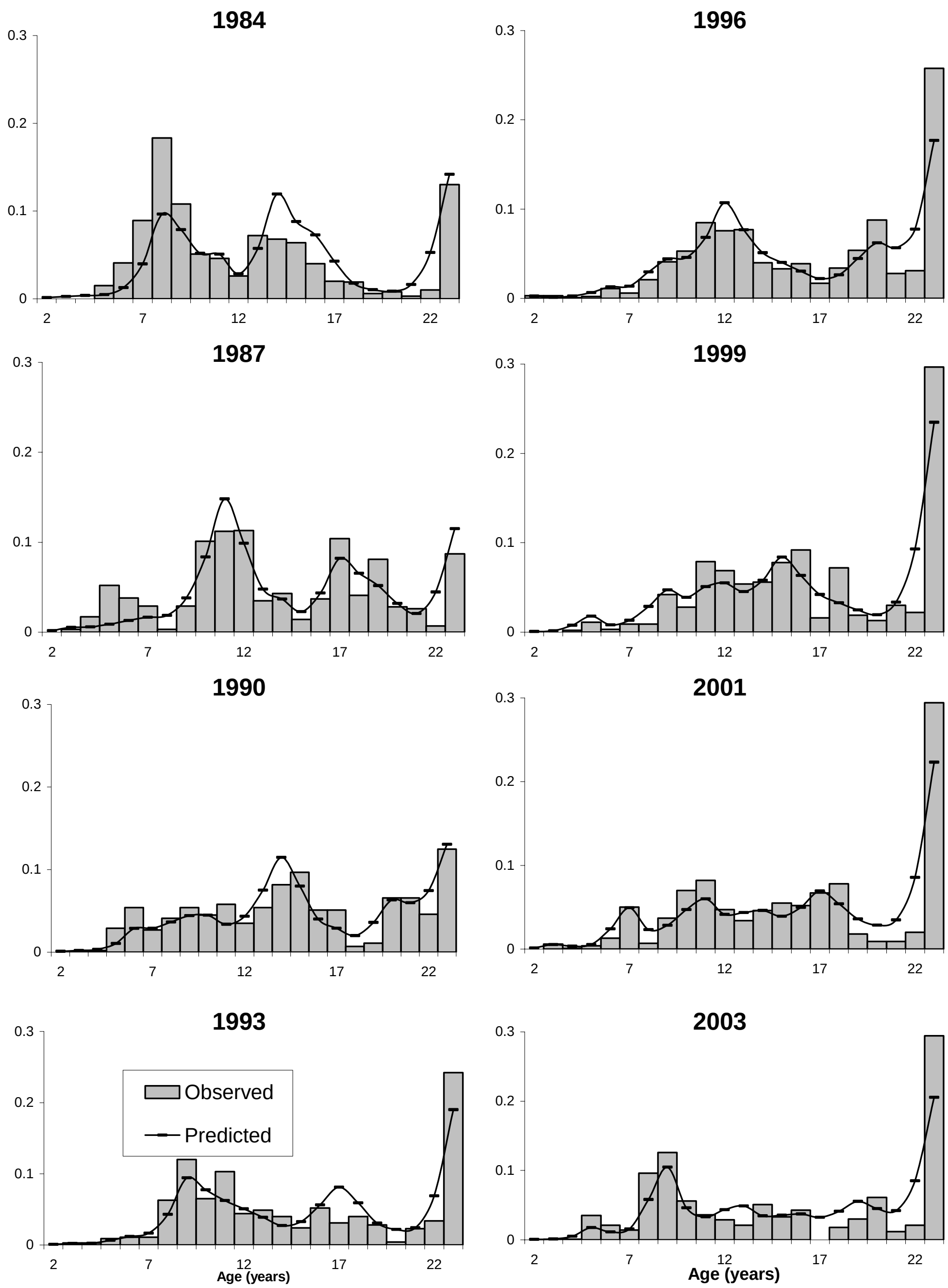

Figure 9-13. –Observed and predicted survey age compositions from Model 1.

Model 1

Fit to Fishery Size Compositions 1990-1997 (Not fit for years with no age composition)

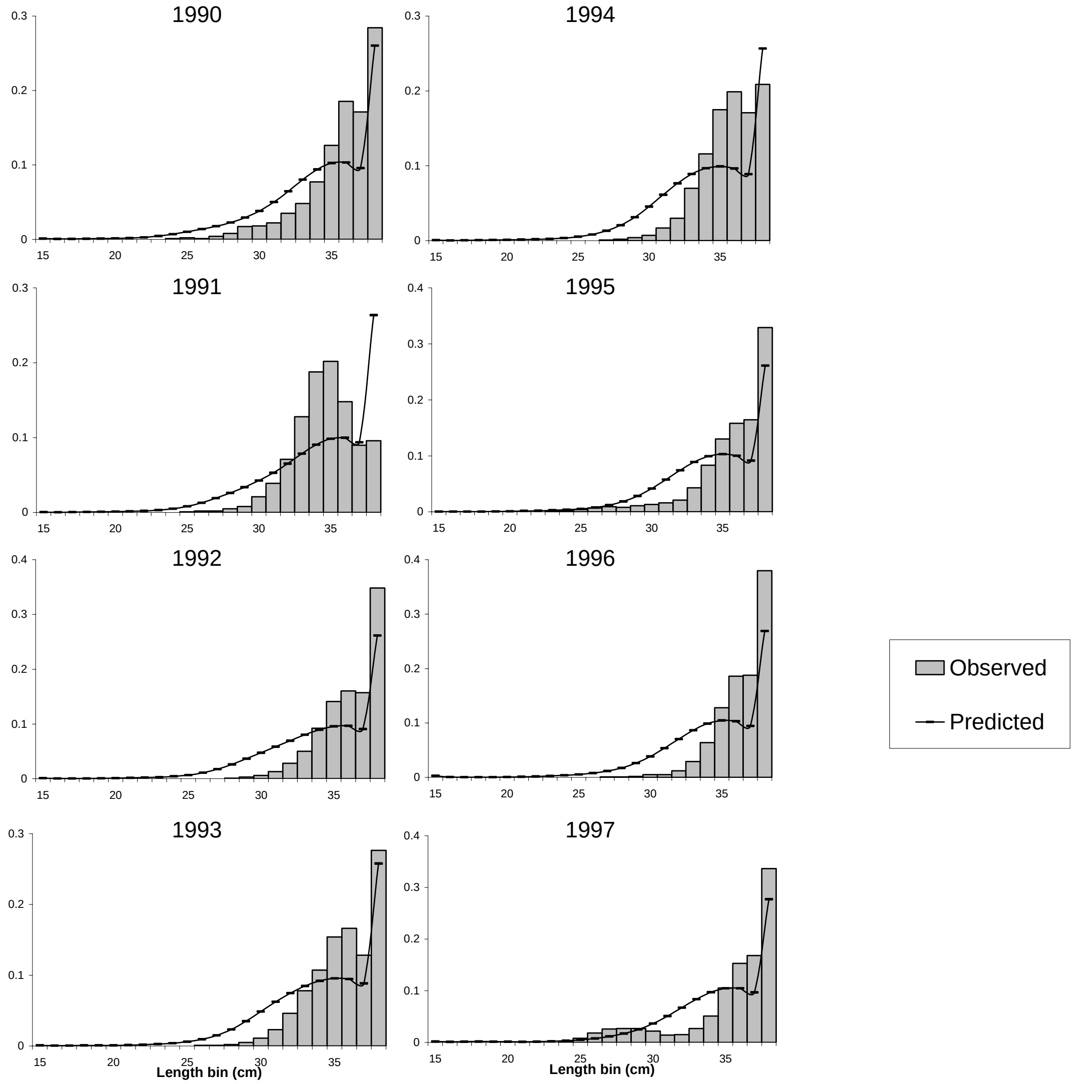

Figure 9-14. –Observed and predicted fishery size compositions from Model 1.

Model 5

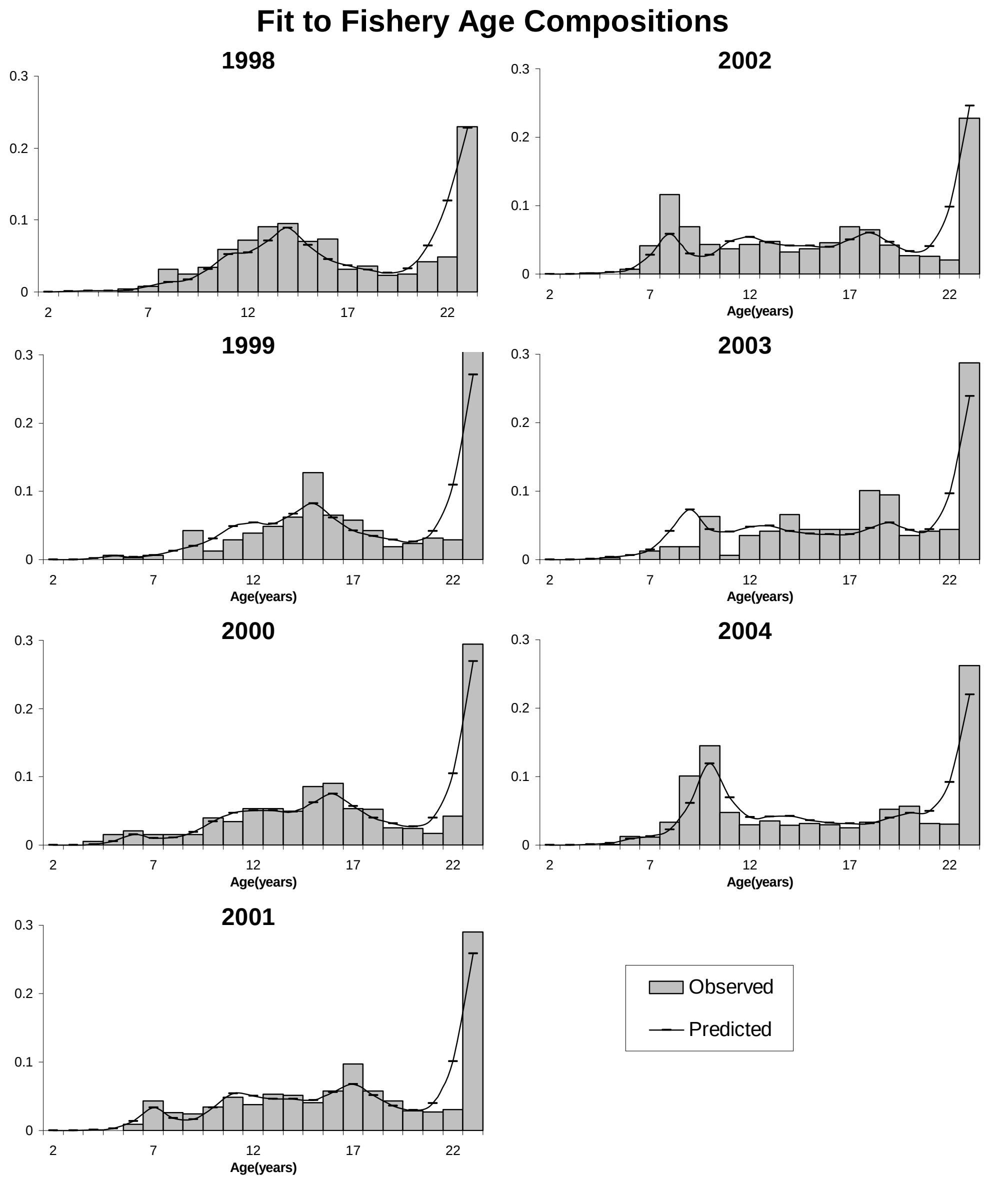

Figure 9-15. –Observed and predicted fishery age compositions from Model 5.

Model 5

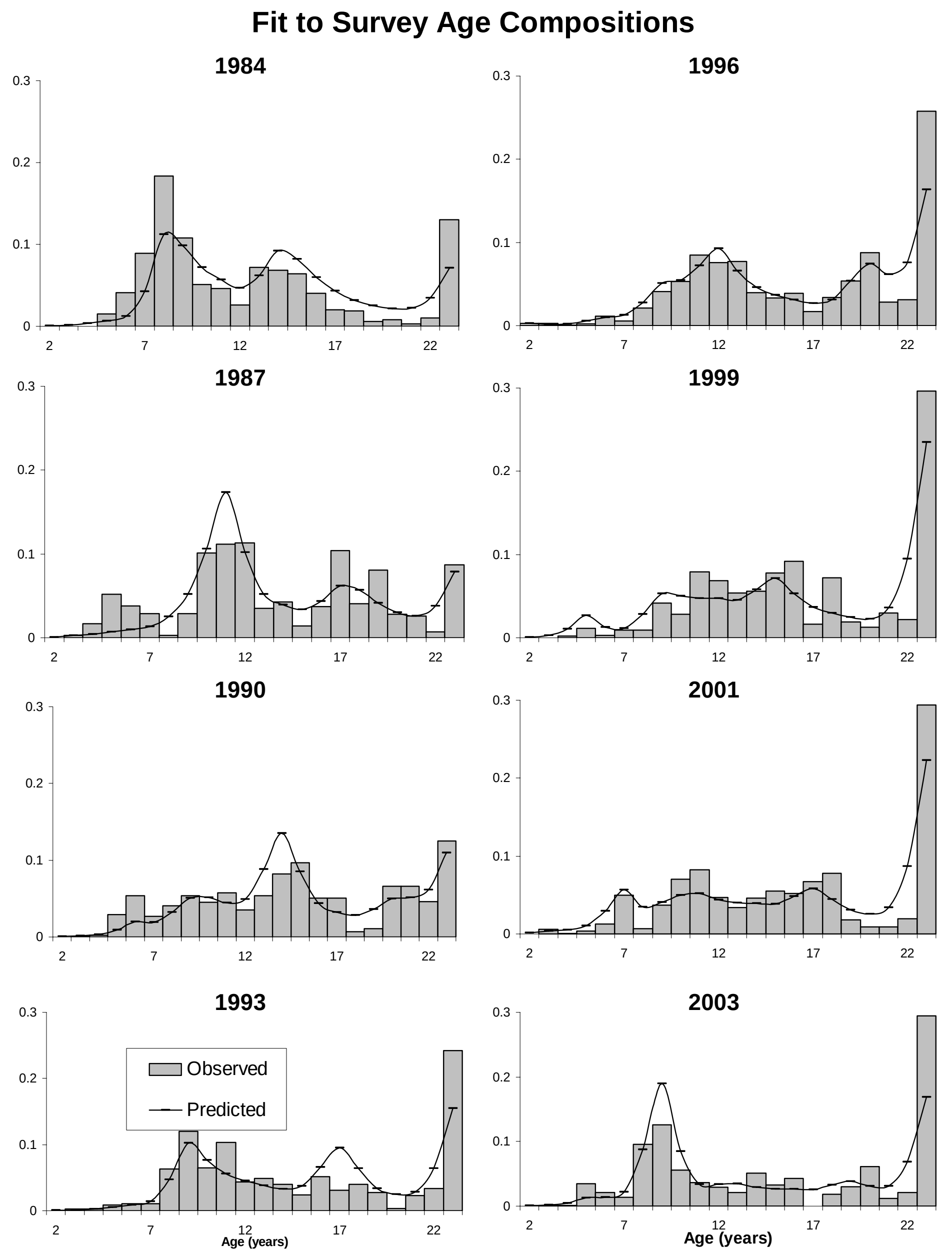

Figure 9-16. –Observed and predicted survey age compositions from Model 5.

Model 5

Fit to Fishery Size Compositions 1990-1997 (Not fit for years with no age composition)

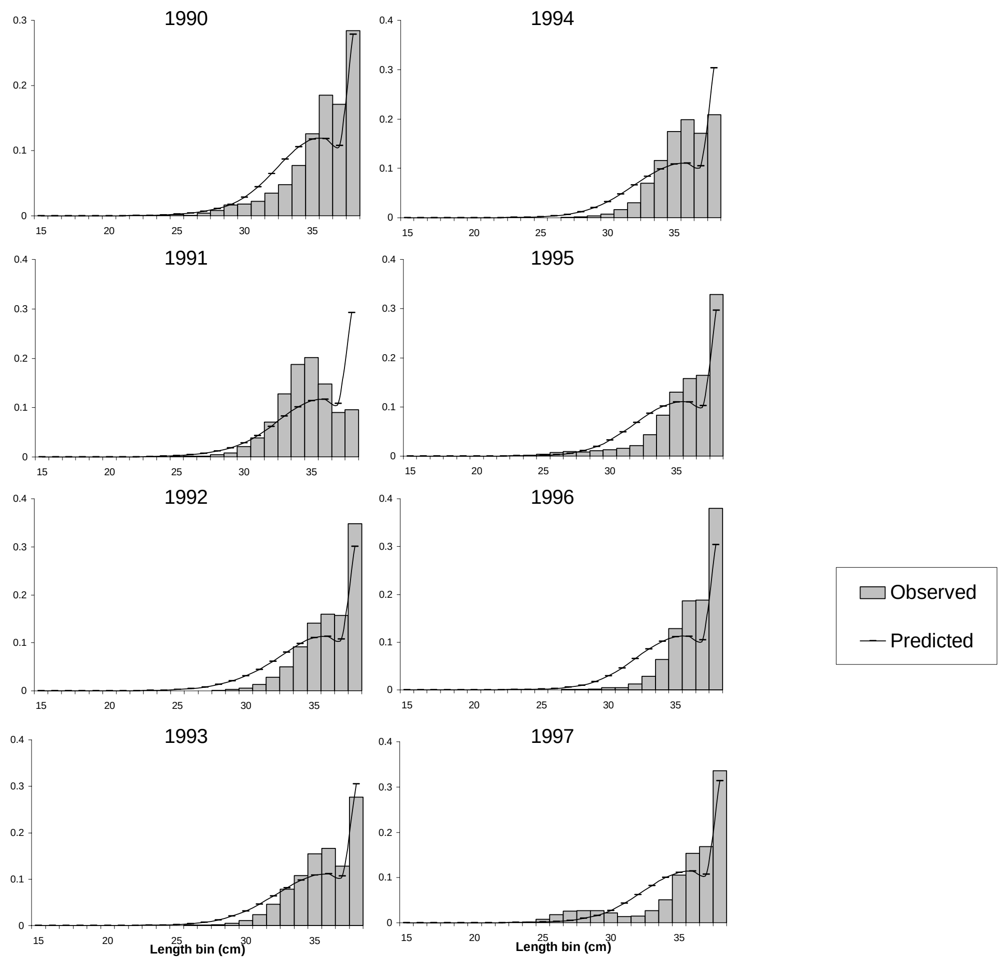

Figure 9-17. –Observed and predicted fishery size compositions from Model 5.

Fishing Mortality

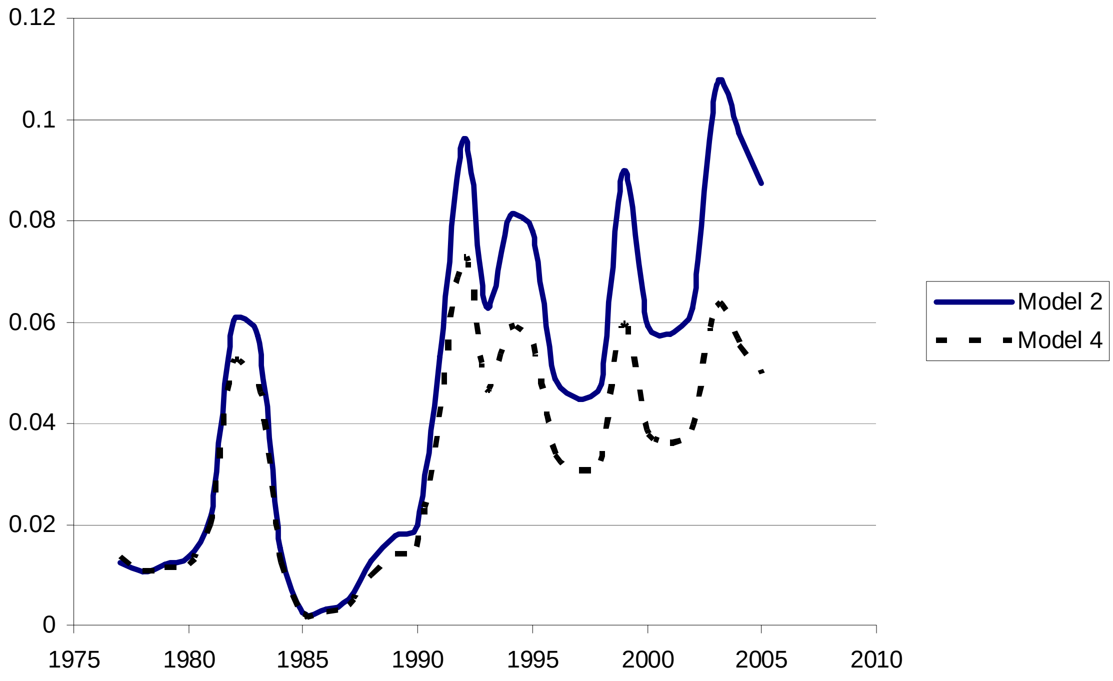

Figure 9-18. –Fully selected fishing mortality from Models 2 and 4.

Survey CPUE

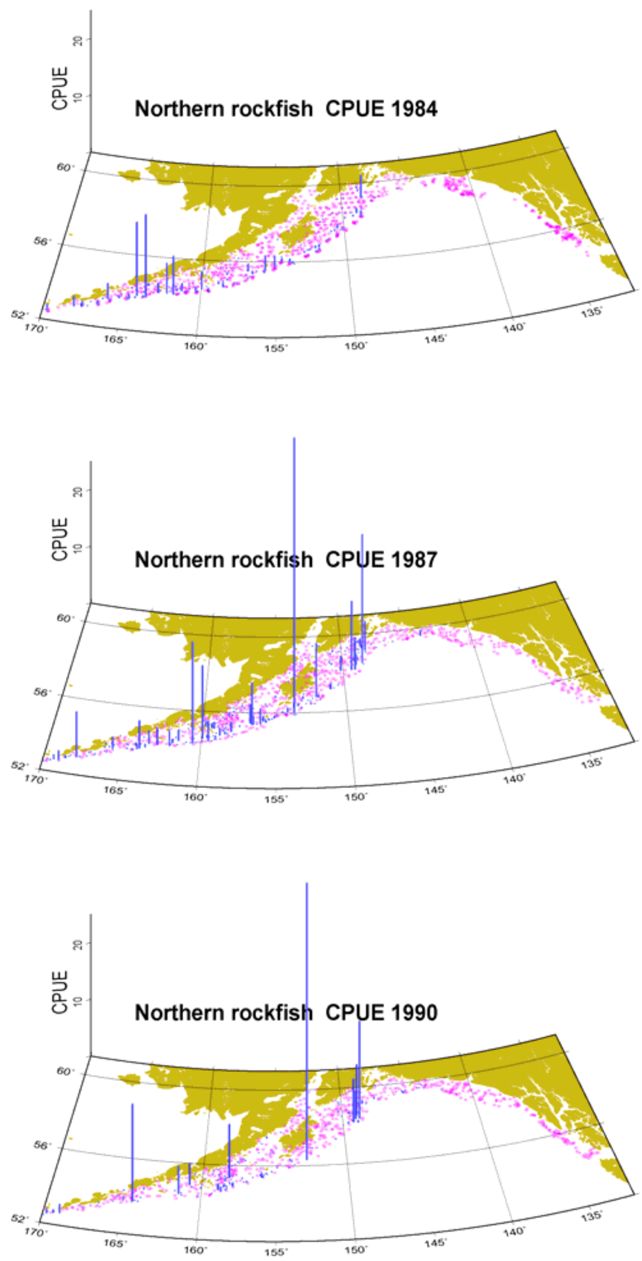

Figure 9-19. Distribution of northern rockfish CPUE from Gulf of Alaska bottom trawl surveys (height of vertical bar is proportional to CPUE by weight).

Survey CPUE

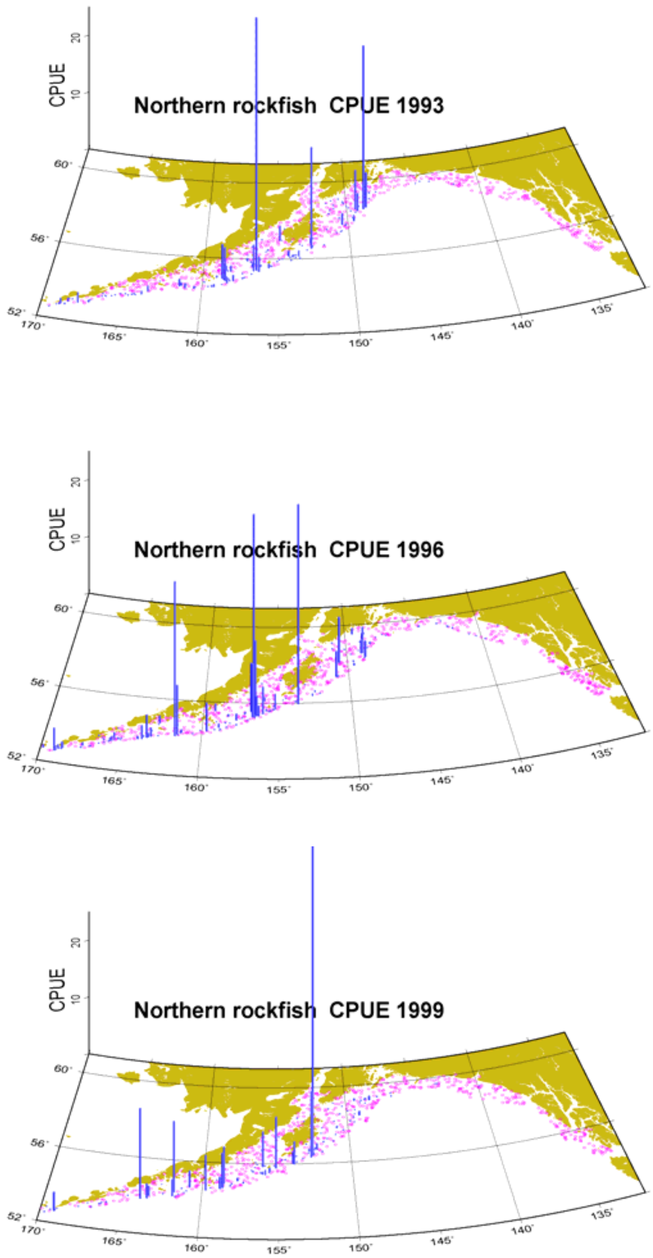

Figure 9-19. Continued.

Survey CPUE

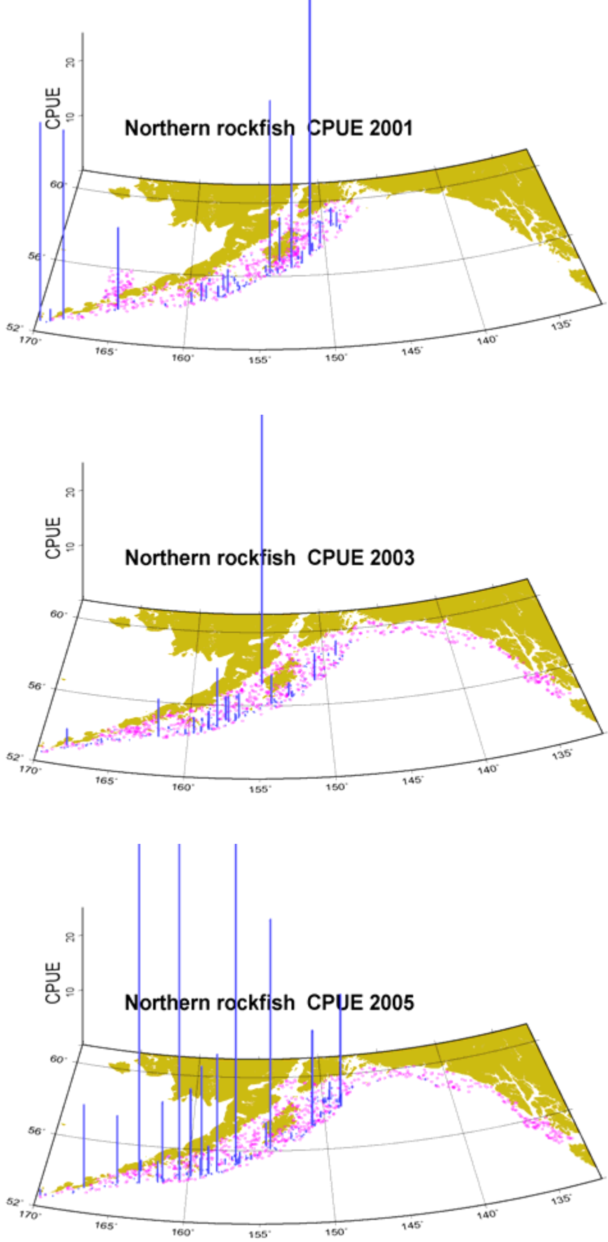

Figure 9-19. Continued.

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